United States
Department
of Agriculture

Forest Service

**Rocky Mountain
Research Station**

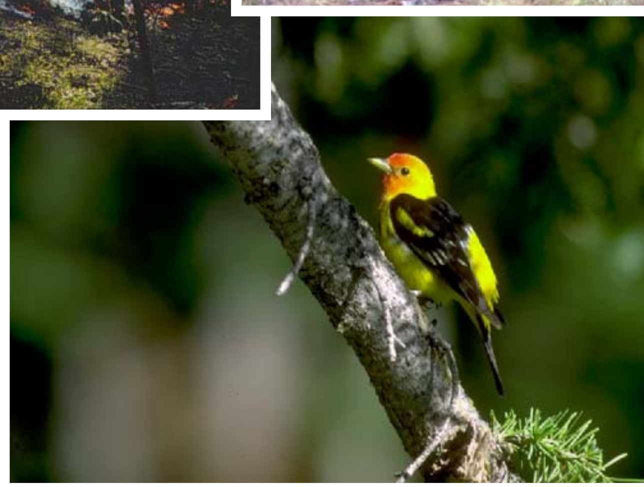
General Technical
Report RMRS-GTR-17

September 2000

The Bitterroot Ecosystem Management Research Project: What We Have Learned

Symposium Proceedings
Missoula, Montana
May 18-20, 1999

Bitterroot
Ecosystem Management
Research Project



Abstract

Smith, Helen Y., ed. 2000. **The Bitterroot Ecosystem Management Research Project: What we have learned: symposium proceedings; 1999 May 18-20; Missoula, MT**. Gen. Tech. Rep. RMRS-GTR-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 154 p.

The varied topics presented in these symposium proceedings represent the diverse nature of the Bitterroot Ecosystem Management Research Project (BEMRP). Separated into six sections, the papers cover the different themes researched by BEMRP collaborators as well as brief overviews of five other ecosystem management projects. The sections are: Understanding the Ecosystem, Its Parts and Processes; Understanding the People and Their Relationship to the Ecosystem; Implementation for Specific Landscape Areas; Overviews of Other Ecosystem Management Research Projects in the West; Fieldtrip Abstracts; and Poster Session Abstracts. The papers presented here are from a symposium held in order to summarize research conducted under the first five-year charter for BEMRP. The symposium was held 1999 May 18-20 in Missoula, Montana for interested public, land managers, and researchers.

Keywords: ecosystem management, forest succession, social sciences, landscape-scale modeling

Editor

Helen Y. Smith is an Ecologist with the Fire Effects Research Work Unit at the Rocky Mountain Research Station, Missoula Fire Sciences Laboratory in Missoula, Montana. She received a B.S. degree in wildlife biology and an M.S. degree in resource conservation, both from the School of Forestry at The University of Montana. Her research interests include ecological restoration, and relationships between fire and invasive plant species.

Acknowledgments

I would like to express my gratitude to Janie Canton-Thompson for reading through the document and finding several editorial errors that I had overlooked.

You may order additional copies of this publication by sending your mailing information in label form through one of the following media. Please specify the publication title and number.

Telephone	(970) 498-1392
FAX	(970) 498-1396
E-mail	rschneider@fs.fed.us
Web site	http://www.fs.fed.us/rm
Mailing Address	Publications Distribution Rocky Mountain Research Station 240 West Prospect Road Fort Collins, CO 80526

The Bitterroot Ecosystem Management Research Project: What We Have Learned

Symposium Proceedings
Missoula, Montana
May 18-20, 1999

Editor

Helen Y. Smith

Table of Conversions

Parameter	Multiply this unit	By this factor	To obtain this unit
Length	feet (ft)	0.305	meters (m)
	meters (m)	3.281	feet (ft)
	inches (in)	2.54	centimeters (cm)
	centimeters (cm)	0.394	inches (in)
	miles (mi)	1.609	kilometers (km)
	kilometers (km)	0.622	miles (mi)
Area	acres (ac)	0.405	hectares (ha)
	hectares (ha)	2.471	acres (ac)
	square kilometers (km^2)	0.386	square mile (mi^2)
	square mile (mi^2)	2.590	square kilometers (km^2)
Basal area	square feet per acre (ft^2/ac)	0.222 (m^2/ha)	square meters per hectare
	square meters per hectare (m^2/ha)	4.496 (ft^2/ac)	square feet per acre
Flow	cubic feet per second (ft^3/s)	0.028 (m^3/s)	cubic meters per second
	cubic meters per second (m^3/s)	35.32 (ft^3/s)	cubic feet per second
Application rate	pints per acre (pt/ac)	1.164	liters per hectare (l/ha)
	liters per hectare (l/ha)	0.859	pints per acre (pt/ac)

Pesticide Precautionary Statement

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Contents

Bitterroot
Ecosystem Management
Research Project

1. Introduction

Bitterroot
Ecosystem Management
Research Project

The Bitterroot Ecosystem Management Research Project: How Did It Happen?

Clinton E. Carlson
Leslie Weldon

Greg Jones asked last winter if Leslie Weldon and I would present a synoptic paper on the early history of the Bitterroot Ecosystem Management/Research Project (BEMRP). I agreed, as did Leslie, but as you can see she is not here. Leslie had other last-minute commitments to deal with so what you see is what you get. There is far more detail about BEMRP than time here permits; I hope this summary suffices. I've written this strictly from memory, so I hope I have it mostly straight! I'll apologize right up front for any names I've left out.

The BEMRP originated in 1993 as part of a nationwide Forest Service initiative to spark interest in forest ecosystems research. After receiving notice of the Forests Ecosystems Research Program administered by the Forest Service national headquarters in Washington, DC, I discussed in depth with Steve Arno the implications of such a project, should we be successful in receiving funding. Guidelines for proposals required that the work (1) must address forested ecosystems, (2) should involve National Forest Management, (3) should involve the public, and (4) should have a strong cooperative tie with a university. We had to decide quickly who the primary partners would be. Steve and I jointly agreed that the Bitterroot National Forest would be ideal for ecosystems research and that the University of Montana (UM), one of the premier Forestry Schools in the U.S.A. physically located about 100 meters from the Missoula-based Intermountain Research Station offices, would be the ideal University Cooperator.

The Bitterroot National Forest (Bitterroot Forest), for several reasons, was a logical choice of venue. The lower elevation habitat types experienced significant change in vegetative characteristics during the last 100 years. Sites previously dominated by pine (*Pinus ponderosa*) and larch (*Larix occidentalis*) are now exploited by Douglas-fir (*Pseudotsuga menziesii*) and grand fir (*Abies grandis*), and were/are highly susceptible to fire, insects, and disease. The Bitterroot NF was, and still is, but one example of similar situations extant in the western U.S.A. The Bitterroot Forest most certainly would be an excellent laboratory in which to study methods to restore forest health. Indeed, Steve Arno and I back in the late 1980's initiated new research on the Bitterroot Forest as part of the New Perspectives program administered by the Forest Service's Washington Office (WO). That research was done at Lick Creek, on the Darby Ranger District, and focused on restoring ponderosa pine in an ecosystem tracking towards domination by Douglas-fir. The University of Montana was a joint partner; Dr. Carl Fiedler headed up the effort on testing the Selection silvicultural system relative to pine restoration. As part of the Lick Creek Studies, we helped Rick Flock and other District folks introduce our ideas to the Bitterroot public; the District and the Station jointly developed the research ideas and objectives. The District took care of contracting for tree harvest and developed and executed the burn plans. We worked together very closely. So this work at Lick Creek really set the stage for future cooperation in forest ecosystems research between Forest Service Research, Forest Service Management, and the University of Montana.

Public interest in forest management on the Bitterroot Forest had been high for about 25 years. The Bitterroot Valley was "found" in the early 1970's. Since then, the valley has experienced unprecedented exponential growth as people have moved here to enjoy the scenery, recreation, and whatever else drew them. The influx of people brought criticism of forest management on the Bitterroot National Forest. People did not like the appearance of clearcuts, of unsightly road bank scars on the land, of logging-induced siltation of streams, and other concerns. They took a proactive stance that resulted in the Bitterroot Controversy of the early 1970's and continues even today. So what better place to test new ideas in forest ecosystem management and gain public input? The University of Montana was a logical player because of close physical proximity to the Intermountain Research Station and current cooperative research.

I assembled a small team to develop a research proposal. As I recall, Steve Arno, Jack Lyon, Mick Harrington, and I represented the Intermountain Research Station; Cathy Stewart and Janet Johnson carried the Bitterroot National Forest flag. We agreed that the proposal would have an ecological focus in tune with restoring forest health through vegetative management. The proposal recognized the need to study flora, fauna, and public perceptions of ecosystem-based management, along with the need to model interactions among them. The proposal met with high enthusiasm in the WO. The idea of conducting cooperative research in an ecosystem adversely affected by past management actions and highly visible to a vocal public seemed to be what the Program Administrators were looking for. They funded BEMRP for an initial five-year period and then continued the funding in 1998.

The BEMRP Organization

Once funded, we had our work cut out for us. The astute listener/reader will have noted by now that the University of

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Clinton E. Carlson is a retired Project Leader of the Forest Ecology and Management Research Work Unit at the Rocky Mountain Research Station, Missoula, MT. Leslie Weldon is a Special Assistant to the Chief of the Forest Service, Washington Office, Washington, DC.

Montana was not involved in proposal planning. I did call Dr. Robert Pfister during the planning process to ask him if UM would want to be a cooperator. His response still rings in my head: “We’d better be!” In retrospect, UM should have been involved in proposal development. Once we learned that our proposal was successful, I called Dr. Pfister and invited his participation in developing specific research plans. He, of course, was very helpful.

The original proposal was to study forest vegetation, fauna, people, and modeling. It seemed natural to structure the BEMRP management team accordingly. Thus, Steve Arno chaired the Vegetation Research Group (RG), and Jack Lyon chaired the Fauna RG, Madelyn Kempf from the Bitterroot NF chaired the Human Dimensions RG, and Greg Jones was conscripted to head up the modeling effort. The BEMRP management team also included Chuck Prausa from the Bitterroot NF and Leslie Weldon, District Ranger for the Stevensville RD. Later on we added Martin Prather, an ecologist, as representative from the Northern Region, Forest Service. For reasons still obscure to me, I was chosen to direct the entire BEMRP effort. We gave the management team a name: the Bitterroot Interdisciplinary Research/Development Team (BIRD). Once again, the astute listener/reader will note that the University of Montana was not represented on the BEMRP management team. We fully intended for UM to be there, but interpretation of FACA (Federal Advisory Committee Act) prevented us from installing anyone but a federal employee mainly because BEMRP would be setting budgets and future management protocol.

Each committee chair set about staffing their committee. At the committee level, FACA allowed University and other non-Forest Service participation. So each committee was well rounded with appropriate expertise. The initial task of each committee was to develop a program of work. They had to decide on new research needed, demonstrations projects, public involvement and so on. The committees functioned unbelievably well. Steve Arno’s Vegetation group initially came up with over 25 studies pertinent to BEMRP goals. Jack Lyon’s Fauna group had seven or eight. Greg Jones already had some neat modeling effort in progress, and Jimmie Chew’s SIMPPLLE system for modeling forest vegetation change seemed a natural. The Human Dimensions group under Madelyn Kempf’s leadership, along with Leslie Weldon’s invaluable help, developed a fine slate of work to bring the public on board with BEMRP.

The BIRD team had the final decision for the program of work. A primary responsibility was to assure that studies would have a common denominator, that they could be “linked.” The linkage variables were to include habitat type, slope, aspect, elevation, vegetation structure, and land form. It was not physically nor financially possible to create a master study design wherein all fauna and vegetation studies would use common plots to assimilate data. We thought the better approach would be to let each study stand by itself albeit with the linkage variables. Generalizing to the next higher principle would allow concepts to be integrated among research disciplines and allow viable input to SIMPPLLE and MAGIS, the two primary models that BEMRP would depend upon. So our approach to ecosystems research was one of dealing with broader generalities gained from individual studies rather than infinite nitty-gritty detail. I have witnessed other research that portends to expose the innermost functioning of ecosystems and could only conclude that one may be more successful in trying to predict Brownian motion! One example is the CANUSA Spruce Budworms R, D, & A Program. A major goal of CANUSA was to expose population dynamics of the insect so that future outbreaks or population collapses could be predicted. Several years and many millions of dollars later not much progress had been made. Near the end of the CANUSA program a general west-wide collapse of budworm populations occurred: no one could answer why.

What Have We Learned?

Can the same be said of BEMRP after five years of effort—that no one can provide answers to important questions on ecosystem-based management? I think BEMRP is much better than that. Through BEMRP and cooperative efforts, very good information has been developed about relationships of forest vegetation to fire history, about how to underburn successfully in dry habitats, about effects of various ways to reduce tree density without clearcutting, about how to better control noxious weeds, and on and on. We have new and valuable information on movements of wolverines (*Gulo gulo*), martens (*Martes americana*), fishers (*M. pennanti*) and other fauna in relation to forested habitat. We have a better idea on how the public perceives forest management. Computer models to assist land management planning have improved immensely. We have a better idea of what questions to ask of our forested ecosystems. And we developed a spirit of cooperation among National Forest Management, University of Montana, Forest Service Research, and the public that is unprecedented. *BEMRP has been a highly successful program and will continue to be so.* We most certainly, in part due to BEMRP, have the *knowledge* to manage effectively in forested ecosystems without degrading the components. Whether or not we can move ahead and make a significant dent in restoring fire-dependent ecosystems to meet current and future needs that forests can provide to our public is a different and highly charged political question that will be debated ad nauseam in the future.

What most defined the need for the Bitterroot Ecosystem Management Research Project was the time of change and transition in which we found ourselves. A different approach was needed to help us move along our mission of land stewardship. We all know the history. It seems obvious by now, but worth saying again: We are all in this together. Our work is on behalf of citizens both locally and nationally. The choices made on national forests affect all lands. These effects extend to downstream or upstream landowners, to adjacent watersheds, and cumulatively to our hemisphere and globe.

If there is one thing we’ve found from our past management, it is that we are on a continuous learning journey. Change is inescapable. Natural and human caused change on the landscape, change in people’s needs and desires, change in economic trends. Change in our understanding of the natural world.

We formed this partnership to find ways that are helping us to *work with* a changing environment, rather than holding on to outdated thinking. Efforts like the BEMRP allow us to have a positive outlook, face the challenges, and push forward to success in land stewardship. The work we do is to better the land, and ourselves and to leave something good for those who come after us. BEMRP brought together all of us to make a difference for the land. Each of us offers something critical to the process:

- Scientific expertise with a better insight into long-term land management challenges and capabilities.
- Land management expertise with a better idea of how carefully directed research can create new stewardship options and ensure better outcomes.
- Most importantly, the public's active commitment to be heard and to keep the BEMRP focus where it needs to be—in service to citizens and to the land entrusted to the Forest Service to manage.

In five short years, we've made amazing progress. We stepped out into unknown territory, took risks, identified new information needs, and broke trail for other pioneers to continue exploring. BEMRP has been successful because of its commitment to cooperating, sharing findings, asking new questions, and being flexible.

For this we congratulate you and thank you. Leslie and I wish you only the best of luck as BEMRP continues developing and implementing ways to restore and protect the ecosystems in the Bitterroot Valley and elsewhere in the Rocky Mountain West.

Keynote Address: Sustaining People and Ecosystems in the 21st Century

Perry Brown

An Historical Context for Ecosystem-Based Management

In its various forms we have been talking about and discovering the principles of ecosystem-based management for over a decade and yet we still are in very early stages of uncovering its many dimensions and implications. This is not surprising since ecosystem-based management is a radical departure from the model of natural resource management that evolved over the previous century. What is it that we are unfolding with ecosystem-based management and what might the future hold for us? These are questions I will briefly discuss and that will form the meat of some of this conference.

In its simplest form, ecosystem-based management is large-scale, collaborative and integrative management that focuses attention on sustainability of whole systems, to meet the desires of humans, I might add. It is a response to a radically changing social situation, a reaction to what we have done to our environment, and in response to knowledge developed from science and observation. It goes beyond the individual plant and beyond the stand to deal with the complex we have constructed as the ecosystem, the complex of plants, animals, soil, water, and air and their interaction that makes a whole and coherent place. It cuts across ownership boundaries, thus demanding that for its integrity, collaboration among owners takes place. It deals with the integration of its many parts in all the intellectual ways that integration might be defined. Ecosystem management is a new way to look at and deal with the environment; it is an expression of modern values.

In American natural resource administration, values toward the environment and how it might be treated have clearly evolved over time. From an early taming of the wilderness and an exploitation of natural resources for settlement, the parallel values of romanticism and utilitarianism emerged as prominent themes in the 1800's. Romanticism often has dealt with an idealization of nature and the contributions of nature to the human spirit. Utilitarianism, in counterpoint, has dealt with the material needs of the human condition, attempting to ensure that natural resources are available to meet the expressed material needs of people. Neither is inherently right nor wrong; they represent different ways to view the environment and what it might mean for people and they both have people at their center. One might also observe that they both are necessary since people require both material and spiritual sustenance.

In an interesting play carried out over the 20th Century, natural resource policy has contrasted these two perspectives. We formed a utilitarian agency, the USDA Forest Service in 1905, and a year later passed the Antiquities Act, to preserve cultural and environmental values. A few years later, we established the National Park Service, to be followed in just a few years by the passage of the Mineral Leasing Act. Jumping over a lot of relevant legislation and events, we find that in 1960 we passed the Multiple Use-Sustained Yield Act to be followed soon after by the Wilderness Act and related preservation oriented legislation.

As we moved through the 1960's, a new "ism" emerged that focused on health of the environment and living spaces for people. This we might reasonably call environmentalism and it was a response to both romanticism and the management of utilitarianism. It began with recognition of a despoiled and polluted environment (ala Rachel Carson and *Silent Spring*) and has emerged with a focus on the integrity of landscapes. In the ism vernacular and the current focus on landscape integrity, what has emerged might be labeled ecosystemism. No matter what its current label, it is leading us toward a new paradigm for environmental management.

The historical arrangement that ecosystemism is replacing is one built in a different time and by and for a different people. The social arrangement that has been displaced is one where the values of a relatively small elite had control over decisions about natural resources. This was neither good nor bad, but simply the social-political model of the time. This elite defined and identified what were relevant natural resources; they specified the desired outcomes from resource management and use, established the institutions (policies, rules, organizations, etc.) relevant for getting the desired outcomes, and specified the management practices that were appropriate for managing the resources. It was a neat and tidy system that we had; agreement was relatively assured, at least where significant dissent could be excluded.

The primary management paradigm for natural resource management was professional managers making rational scientific decisions and implementing them on the ground to obtain what the elite said was important. This implementation, until fairly recent times, was undertaken with crude technology (at least by our standards and capabilities today) and to serve a much smaller, less global population than we have today. And, while it had a scientific base, what was known through science was much less than we know today.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Perry Brown is the Dean of the School of Forestry, University of Montana, Missoula, MT.

What Has Happened to Change the Situation?

We have had an information revolution where access to information is nearly instantaneous, and where both accurate and inaccurate information and images are readily available to nearly all. Just go to the Internet to see and read nearly anything you want and don't want to see. Or, watch the nightly news on CNN to learn what is happening at the moment nearly anywhere on the globe, and sometimes even beyond the Earth. We are inundated with real time information, and a lot of it. It is there for us to use and abuse, and we seem to do a lot of both.

We have enfranchised a plurality of interests who now have been accorded a legitimate interest in natural resource decision-making. Not that small elite that I talked about before, but a lot of people have been enfranchised. As the spirit of inclusiveness has permeated natural resource discussions, the plurality of interests has expanded and decision-making has become far more complex. No longer are the values of the small elite the controlling values regarding environmental management. There are many more voices to which we must attend, and they offer many more ideas for our consideration.

Participatory democracy has become the mode in vogue, even at the expense of a sound history of representative democracy. Individuals and groups demand to be at the table making decisions and determining whether or not they will be implemented. This has a populist appeal in its inclusiveness, but it cuts at the heart of professional management and action and sometimes, as we all know, renders expertise mute.

We have recognized that many of our environmental problems are large, complex, technical, and very difficult to solve. Dealing with human communities, with migratory and resident wildlife, with forest mosaics, with global pollution and climate change and myriad other phenomena is complex and changes the way we view management roles, responsibilities, and practices.

We also have learned a lot more about the environment and a lot more about what we don't know about the environment. This has led to both conflicting scientific pronouncements and to confusion among politicians and publics, while at the same time leading to a more conservation-oriented approach to environmental management. As we have learned, we have become more conservative in our actions through the fear of doing things to the environment that are irreversible. At times this had led to no action, and at other times this has led to ignoring change that is inevitable.

Finally, we have seen what we have done to the environment from ignorance, from the speed and efficiencies of new technologies, and from greed and short sightedness. For example, for decades throughout the 20th Century timber harvesting on public lands was confined to relatively small areas and the visual and ecological disruption of western forests particularly was minimal. In the west, this meant that the carpet of green that was forest was relatively intact. With new technologies, the desire to compensate for the lack of merchantable timber on private lands, and dogma demanding low-cost wood, at almost any cost, we began to visually ravage the western forests. To many, the carpet of green was lost or, at the very least, it was perceived as ragged and moth-eaten, and the reactions were swift and strong—stop clearcutting and in some cases, stop cutting altogether.

These and other factors have led us to search for a system of integrity—the state of being unimpaired with completeness and unity. The search has led us through "new forestry," "new perspectives," "ecosystem management," and "sustainable forestry." All of these are a form of "benefits-based management" which implies striving for the benefits that forests can provide. They are clearly driven by demand side pressures that are expressions of what the currently enfranchised voices want from our forests. The benefits might come in many forms such as personal, economic, social, and environmental. The multiplicity of benefits demanded require a look that is larger in scale, more collaborative, and more integrated than what we have attempted in the past.

Where Are We Going?

There are a lot of words that we now use to describe our values toward and for the environment. A few of the most prominent are "sustainable forests," "biodiversity," and "forest integrity" and these are highly inter-related. In the way that I have defined integrity as the state of being unimpaired with completeness and unity, both the notion of sustainability—that something continues—and a notion of biodiversity—that all of the parts are there to make something complete and unified—are inherent within it.

Sustainability is such a prominent concept today that I might take a look at it for a few moments. We can look at sustainability in a lot of different ways. Is it a characteristic of land management? Does it deal with intergenerational equity? Does it deal with ensuring the bequest to future generations? Does it deal with some form of development that is long-lasting? Does it deal with the flow of goods and services? Does it deal with just forests or also the social context in which they occur? The answer in a global sense is yes; it deals with all of these concepts, ideas, and forms.

It does this because we express varied objectives for our forests. We want them to be forests, whole and complete. We want them to serve our material needs. We want them to serve our spiritual needs. We want them so our progeny can have the experience of forests. We want them to support our communities. We want them as part of our identity. We want them to express the best of who we are as a responsible and caring people.

Whether we focus on sustainability, biodiversity, integrity, or some other modern concept of environmental management, we need new forms and structures for management that are reflective of a changing history, an expanded scientific base, a more widely enfranchised populace, a broader view of both the definition and services of forests, and desires for long-term responsible relationships with our environment. And, the response of the professional natural resource community, while at times reluctant to change, has been to change, beginning a process of experimentation and adaptability. Ecosystem-based management is one of the creative responses that have expanded the scale of discussion and practice, that have led to experiments with ways to collaborate across ownerships and disciplines, and that have stimulated focus on integration and environmental management. We have thrown off the old model of an elite making the decisions and directing the actions of professional managers with a relevancy of multiple voices and multiple objectives, demanding that professional managers focus on integration and integrity within and across environmental and social systems. This is a formidable challenge and one where research has a huge role. The issues range from the meanings that people attribute to forests to the impacts of management decisions on soil, water, wildlife, and vegetation.

Where Does BEMRP Fit Into All of This Activity?

There are a lot of activities to be undertaken to forge a new environmental management paradigm with the BEMRP effort being one that is making contributions. For the first five years, those that we are celebrating in this symposium, the mission was "To predict landscape level influences of vegetation management on multiple resource outputs and values in an altered Rocky Mountain ecosystem and to demonstrate to the public the feasibility of landscape-level rehabilitation (restoration) management." This got at a piece of the issue, and the mission for the next five years begins to expand this vision as it "is to strengthen the scientific theory and practice of managing Rocky Mountain ecosystems at the landscape level in the context of social, economic, and ecological opportunities and constraints." What this suggests to me is exploration and experimentation, integration and synthesis.

If we are to fulfill the promise of ecosystem-based management that truly is driven by the benefits that the people want, we must approach our activities with a spirit of experimentation and learning. We must become a learning society and plan to learn just as hard as we learn to plan. BEMRP, with one cornerstone in science and research, is an instrument for learning. It also is an instrument for fostering opportunities for collaboration and integration across administrative boundaries and ownerships; across disciplines; across research and management; and across function, uses, and outputs. From what BEMRP scientists, managers and publics learn, BEMRP also can be an instrument for synthesis and a molding of a new way to manage our environment. These are some of the promises of BEMRP. You need to watch for them in this symposium and you need to facilitate their fulfillment in the next five years of this project.

Where Might We Look for Ideas?

There are a lot of experiments going on and we are at the front of some of them, and other people and places at the front of others. We might look at Europe with its longstanding practice of intensive multiple use that contrasts so starkly with our extensive version of multiple use. In my experience, Denmark and Germany particularly have lessons for us, but so do the other Scandinavian countries.

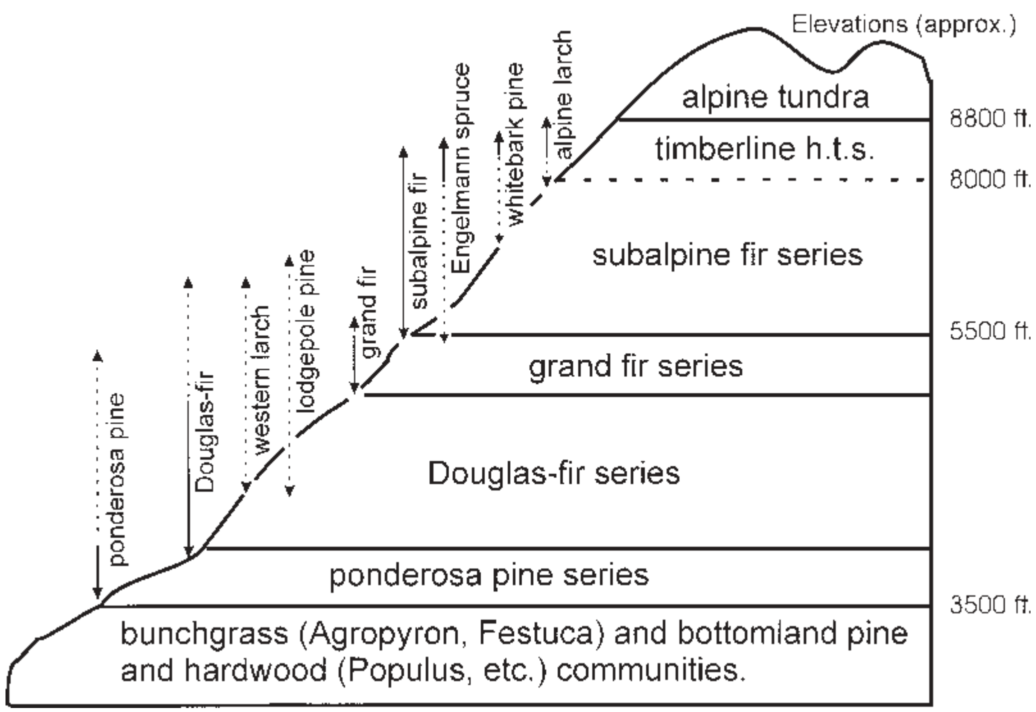
We also might look to Australia with its experimentation in collaborative management or to many other places where disparate management, planning, and policy agencies have been molded into one organization. And, we also might look to our pioneering experiments and ourselves in large-scale collaborative assessment and planning.

The spirit of creativity needs to permeate our look at the possible. We need to envision how things might be and then figure out just how we might get there. We need to think of creative ways to move beyond the present and really explore what the implications might be. At the same time, we need to clearly identify what is and what is not broken before we try to fix it. And we need to identify what can be done better, even if it is not broken. I often tell people that the horse and buggy were not broken—the automobile was simply better. So, we don't just fix things that are broken, but we look for better ways to do things than we have right now. The natural resource management experience of the 21st Century must be one of openness and experimentation—one of seeing the trees, the forest, and the landscape in their many interconnections. It must be an experience of the inclusion of voices and ideas. It must be an experience of maintaining integrity of forests so that social and environmental sustainability can be achieved.

What Does the Future Hold for Us?

No one knows for sure, but it is clear to me that we are forming new structures and practices for environmental management. We are learning, even if slowly. We are on the cusp of figuring out how to ensure forest integrity so that forests are part of our future—and to me, integrity is the essence of sustainability. Forests need to be unimpaired in their function as forests; they need to be complete as forests; they need to have unity of parts and spirit that make them whole, that sustain them as forests today and tomorrow. Sustainability also means the forests are unified with the community of people that care about them for all of the things that caring people want. As we move along the path towards management of sustainability, I challenge you this day to explore how to make BEMRP even a more integral part of the future, especially as you explore the many issues of collaboration and integration that are so essential in dealing with the larger scales and many forces, and with ensuring the integrity of forests as forests in a social milieu.

2. Understanding the Ecosystem: Its Parts and Processes



Typical distribution of forest trees on the Bitterroot Front (from Lackschewitz 1986).

Comparing Historic and Modern Forests on the Bitterroot Front

Michael G. Hartwell
Paul Alaback
Stephen F. Arno

Abstract—A study was initiated in 1995 to measure landscape changes in forest structures between 1900 and 1995. A systematic sampling system was used to collect data on three forested faces on the Bitterroot Front. Over 1,200 tree cores were taken on 216 plots between the elevation range of 4,500 to 7,500 feet. Historic forests were reconstructed through quantitative techniques. Changes are presented in three elevation zones: lower (4,500 to 5,800 feet), middle (5,800 to 6,900 feet), and upper (6,900 to 7,500 feet). Dramatic decreases in fire dependent species and increases in fire intolerant species are shown throughout all elevation zones. Ponderosa pine (*Pinus ponderosa*) has been reduced from 52 percent to 26 percent of total basal area in lower elevations. Douglas-fir (*Pseudotsuga menziesii*) increased its relative percentage of total basal area in the lower zone from 19 percent to 55 percent over the past century. Western larch (*Larix occidentalis*) abundance has declined from 26 percent to 11 percent in lower elevations (4,500 to 5,800 feet) and from 24 percent to only 6 percent in middle elevations (5,800 to 6,900 feet). Lodgepole pine (*Pinus contorta*) has increased its relative percentage of landscape basal area 6 percent in middle elevations and 13 percent in upper elevations (6,900 to 7,500 feet). Whitebark pine (*Pinus albicaulis*) decreased from 39 percent to only 11 percent of total stand basal area in the upper elevation zone.

To provide an historical baseline to aid land managers, we conducted a detailed inventory of representative areas on the northern portion of the Bitterroot Front using plots placed on a systematic grid. At each plot, the current forest conditions and the processes linked to the stand's development were examined. At the same plots, evidence of the historical forest conditions (circa 1900) and the natural processes that shaped the historical stand were also collected. Objectives of the study were to assess changes in stand composition and structure between the historic period, when forests were heavily influenced by natural fire regimes, and the current period, when logging and fire suppression may have become important influences shaping forest conditions.

National forest managers are attempting to develop ecosystem-based management (EM) for the mountain slopes rising directly above the west side of the Bitterroot Valley, which we will refer to as the "Bitterroot Front." The front is a boundary zone between the Bitterroot Valley, which has become a major suburban and rural residential area, and the Selway-Bitterroot Wilderness. How to maintain the diverse values of forest ecosystems along the Bitterroot Front presents a dilemma for land managers on the Bitterroot National Forest. The Bitterroot Front is a highly valued viewshed for about 30,000 valley residents. Immediately west of the front lies the 1.3-million-acre Selway-Bitterroot Wilderness. However, much of the front itself is outside the Wilderness and has been subject to logging, grazing, intensive recreational use, and suppression of all natural fires.

Environmental laws and regulations guide national forest management toward maintaining a semblance of historical ecological processes as a means of perpetuating communities of the native plants and animals. For thousands of years, fire has been a critical process shaping Bitterroot ecosystems, and since 1973 a natural fire program has allowed many lightning fires to burn in the Selway-Bitterroot Wilderness (Brown and others 1994). Starting in 1988, however, fires originating in the Wilderness have periodically threatened private land and homes along the Bitterroot Front, which lies immediately downwind. Although most of the middle and upper elevations on the Bitterroot Front lie within the national forest, much of the lower elevation forest is in private ownership. In the last 25 years hundreds of homes have been built here, many located in hazardous forest fuels. National forest managers are directly or indirectly responsible for protecting forests and homes from severe wildfires.

Methods

This assessment was based on a detailed sample of forest conditions on representative portions of the Bitterroot Front, with large numbers of sample plots measured on systematic grids.

The Bitterroot Front consists largely of broad triangular ridge faces rising above the Bitterroot Valley (fig. 1). The lower slopes begin at elevations of 3,500 to 4,000 feet and are covered with ponderosa pine (*Pinus ponderosa*)-dominated forests. At increasing elevations other species become dominant, with whitebark pine (*Pinus albicaulis*)-dominated forests occurring at the highest elevations, around 8,000 feet (fig. 2). Three ridge faces considered representative of the Bitterroot Front were selected for intensive sampling. On each face a grid of parallel transect lines was laid out, running directly up the slopes (fig. 3). Structure of the current and past forests was sampled on 1/10th acre circular plots located at 500-foot intervals along each transect. See

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Michael G. Hartwell is a Graduate Student, School of Forestry, University of Montana, Missoula, MT. Paul Alaback is an Associate Professor, School of Forestry, University of Montana, Missoula, MT. Stephen F. Arno is a retired Research Forester, Fire Effects Research Work Unit, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT.

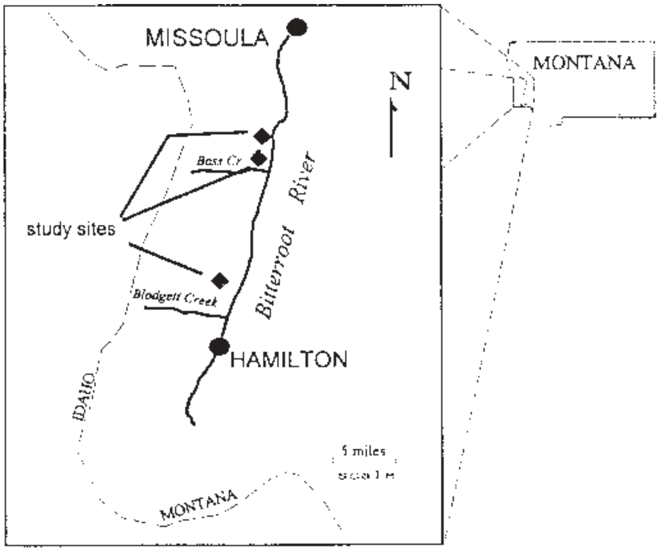


Figure 1—Map of southwestern Montana showing locations of the three study sites (from Hartwell and Alaback 1996).

Hartwell and Alaback (1997) for a detailed explanation of study methods. Transects were established between 4,500 and 7,500 feet in elevation. Areas below 4,500 feet usually were logged in the late 1800's and had more slash burning and other human activity, such that stumps and evidence of previous forests may have been severely diminished. Time constraints and difficult accessibility prevented sampling above 7,500 feet.

To record current stand conditions, all live trees were tallied by species and diameter. Major disturbances related to the development of the current stand—logging, thinning, fires, and bark beetle (*Dendroctonus* spp.) epidemics—were recorded. Studies of forest history in this region suggest that forest conditions in about 1900 were generally still representative of the pre-fire suppression, pre-logging period (Arno 1976; Arno and others 1995). To estimate circa 1900 conditions, increment borings were collected from trees of each species and different diameter size classes to allow calculation of the diameter of each tree in 1900 by measuring and subtracting post-1900 growth from the tree's diameter. Additionally, all dead trees (standing and fallen, greater than 6 inches in diameter) that would have been alive in 1900, were recorded by species and diameter (Arno and others 1993, 1995). Decay classes of Maser and others (1979) were assigned to dead trees and these were later used to estimate time since death. The severities of historical fires associated with the circa 1900 stands—low-intensity underburns, mixed-severity fires, or stand-replacing fires (Brown 1995)—were determined based on trees that survived, fire scar sequences on trees and stumps, and fire-initiated age classes of trees (Arno and Sneck 1977; Barrett and Arno 1988).

A total of 216 plots were sampled for both current and historic conditions in the three study areas. Over 1,200 trees were aged from increment cores and the age-diameter relationships were used to develop regression equations to describe the growth rates of each species (Hartwell and Alaback 1997).

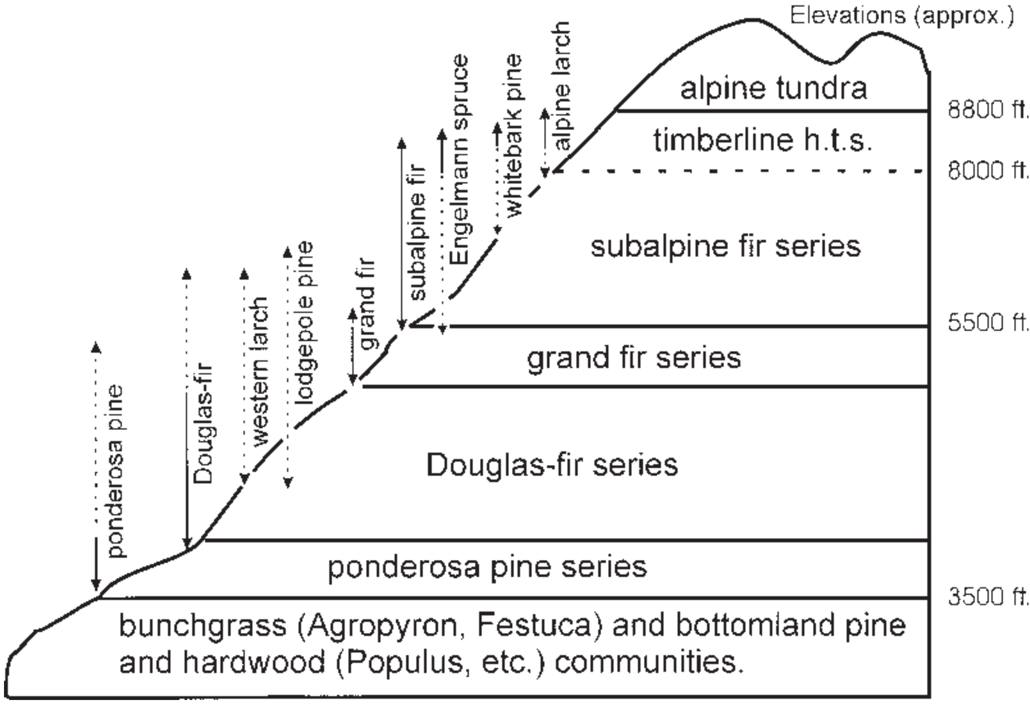


Figure 2—Typical distribution of forest trees on the Bitterroot Front (from Lackschewitz 1986).

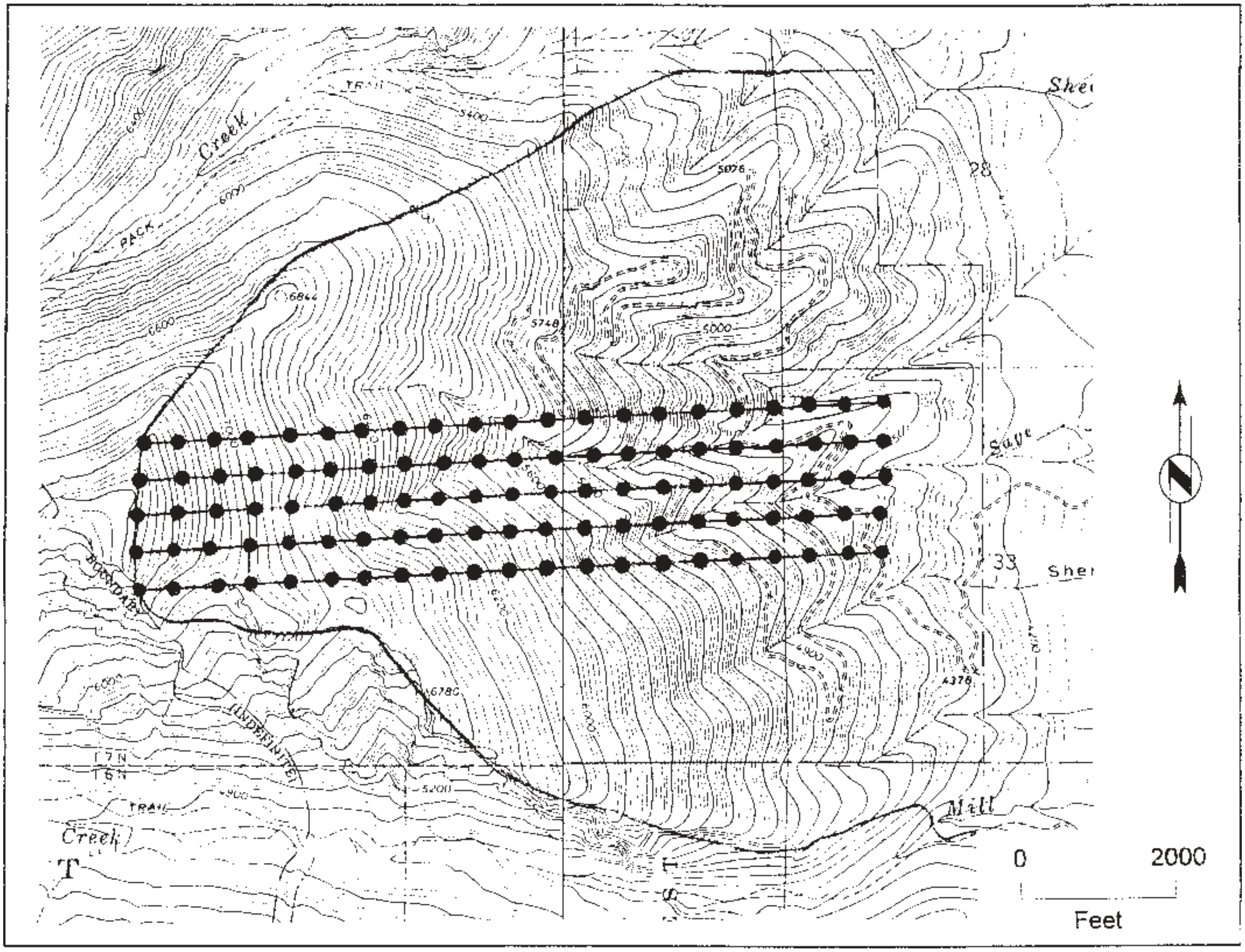


Figure 3—Plot locations on a sampling grid at one of the sutdy sites (from Hartwell and Alaback 1996).

Results and Discussion

At this time, we are able to provide a synopsis of the comparison of historical and current forest composition in the lower, middle, and upper elevations. (When the analysis of the study data is completed, we will be able to report additional information about characteristics of the structure and composition of historic forests.) The 216 sample stands were stratified into three elevational zones linked to historical forest composition. The forests sampled below 5,800 feet elevation were historically dominated by ponderosa pine. Forests between 5,800 and 6,900 feet were dominated by mixtures of lodgepole pine (*Pinus contorta*), western larch (*Larix occidentalis*), Douglas-fir (*Pseudotsuga menziesii*), and subalpine fir (*Abies lasiocarpa*). Forests above 6,900 feet were dominated by whitebark pine and lodgepole pine.

Figure 4 compares the relative basal areas of the different tree species in the lower elevation forests in 1900 and 1995. Basal area per acre is the cross-sectional area of all tree stems and serves as a rough index of tree biomass. According to these data, ponderosa pine was the most abundant tree in 1900, but is now replaced in that status by Douglas-fir. Similarly, western larch was second in abundance in 1900, but has now become a distant third. Logging in the early and mid 1900's removed the majority of large ponderosa pine and larch as well as some of the larger Douglas-fir. Elimination of frequent low-intensity fires, which were characteristic of this zone, allowed Douglas-fir to regenerate in abundance. As small trees, Douglas-fir are more fire sensitive than pine and larch.

Figure 5 compares the relative basal areas of different trees in the middle elevations (5,800 to 6,900 feet). About half of the plots in this zone had experienced logging. The primary fire-dependent tree, lodgepole pine, has maintained its historical abundance. The young lodgepole stands that regenerated after late 1800's fires now contribute more basal area due to growth of these trees. Also, lodgepole pine has regenerated heavily in the clearcuts made during the 1960's, 1970's, and 1980's. Larch, historically a major forest component on cool exposures, is now a relatively minor component. This is probably a result of logging the large

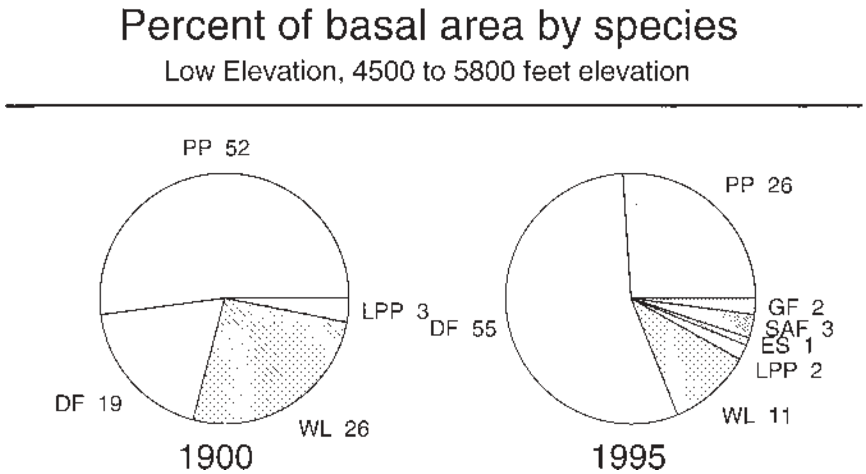


Figure 4—Relative basal areas per acre by species in the lower elevational plots.

trees—although in clearcuts, larch has often regenerated. In partially cut and uncut stands, larch tends to be replaced successionally by shade-tolerant subalpine fir and Douglas-fir. Subalpine fir, the most fire-sensitive and shade-tolerant tree, has increased substantially, presumably as a result of successful suppression of fires. Circa 1900 stands had arisen after mixed-severity fires (killing some trees and leaving others) and stand-replacement fires.

Figure 6 compares the relative basal areas of different trees in the upper elevation study zone (6,900 to 7,500 feet), where no logging has occurred. Historically, whitebark pine was the most abundant species, but today it is a relatively minor component. Today, whitebark pine is abundant only at still higher elevations, from 7,500 or 8,000 feet to tree line, at about 8,800 feet. In contrast, subalpine fir was historically a minor component, but it has become second only to lodgepole pine. Lodgepole pine has expanded in basal area due to its growth on late 1800's burns in two of the three study areas. The data on number of trees per acre by species in historical and modern stands show trends similar to those of basal area, with the number of Douglas-fir (at lower elevations) and subalpine fir (at middle and upper elevations) increasing greatly in modern times. (These data will be reported as the study analysis progresses.)

Table 1 compares the circa 1900 and 1995 stand structures at all 216 study plots (4,500 to 7,500 feet elevation) based on which species had the greatest basal area. Overall, the long-lived fire-dependent trees (ponderosa pine, western larch, and whitebark pine) declined dramatically between 1900 and 1995. The old growth trees of these three species have high value as habitat for cavity nesting birds and mammals, and whitebark pine is a source of large, nutritious

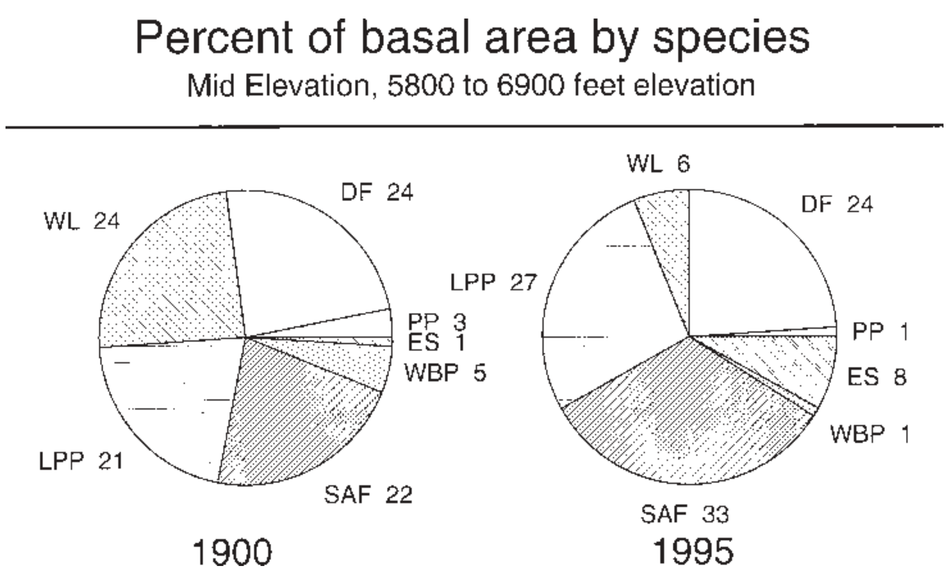


Figure 5—Relative basal areas per acre by species in the mid-elevational plots.

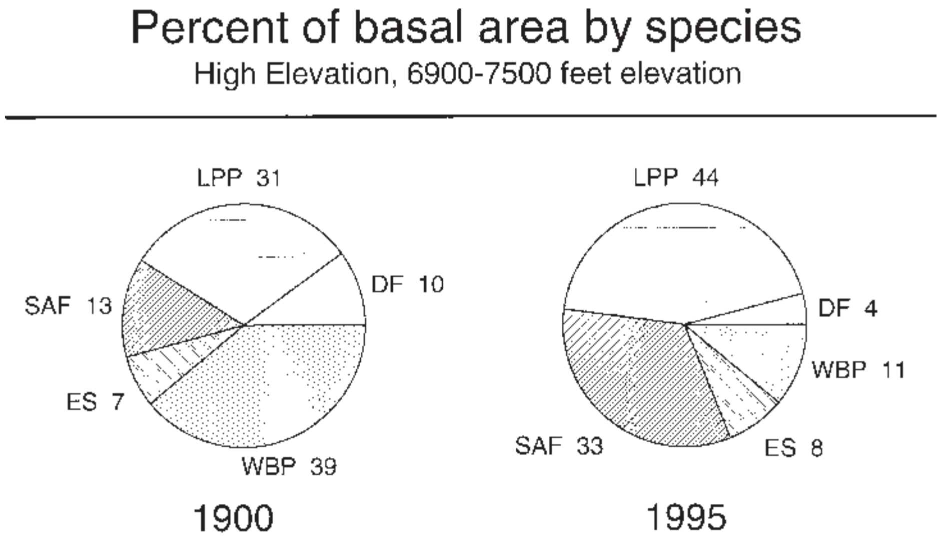


Figure 6—Relative basal areas per acre by species in the upper elevational plots.

seeds, heavily used by Clark's nutcrackers (*Nucifraga columbiana*), squirrels (*Tamiasciurus hudsonicus*), other small mammals, and bears (*Ursus* spp.). The short-lived, fire-dependent lodgepole pine has maintained its former abundance. Fire-susceptible and relatively shade-tolerant trees (Douglas-fir, subalpine fir, and Engelmann spruce [*Picea englemannii*]) have increased in abundance.

These data indicate that changes commonly reported in individual stands are also happening on a landscape scale. These changes vary with elevation and forest type. Forests historically dominated by large old ponderosa pine and larch have been replaced by dense stands composed primarily of small Douglas-fir and subalpine fir. At higher elevations (6,900 to 7,500 feet), mature whitebark pines are disappearing, presumably due to damage by blister rust and competition from subalpine fir and other species. This is shrinking the whitebark pine zone to only the upper half of its historic range, well above 7,500 feet. The lodgepole pine cover type, in the middle elevations, is maintaining its historic abundance. Where fires occur in these forests, lodgepole pine and associated seral shrubs and herbs will probably regenerate in abundance; conversely, if fire protection continues to be largely successful, there will be a loss of seral shrubs and herbs (Arno and others 1985, 1993; Stickney 1990). The strong increase in subalpine fir at middle and upper elevations suggests that where fire is largely removed, landscapes will shift to dominance by fir.

Conclusion

These data indicate that a shift of forest composition and stand structure has occurred on the Bitterroot Front. In general, dense, fir-dominated stands have largely replaced more open ponderosa pine, larch, and whitebark pine forests at lower and upper elevations. Historically, the forests were dominated by long-lived, fire-dependent trees. The new forests are dominated by shorter-lived species that are growing in a structure more vulnerable to insect and disease epidemics and severe wildfires (Hill 1998; Monnig and Byler 1992; Mutch and others 1993; O'Laughlin and others 1993). Change in the forests on the Bitterroot Front is inevitable; the question is whether national forest managers will be able to restore and maintain some of the natural characteristics and processes that were historically associated with these ecosystems.

References

Arno, S. F. 1976. The historical role of fire on the Bitterroot National Forest. Res. Pap. INT-187. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 29 p.

Arno, S.F.; Reinhardt, E.D.; Scott, J.H. 1993. Forest structure and landscape patterns in the subalpine lodgepole pine type: A procedure for quantifying past and present conditions. Gen. Tech. Rep.

Table 1—Number of plots by dominant cover type, named for the tree species that has a plurality of the basal area per acre.

	Species[a]							
Year	PP	WL	WBP	LPP	DF	ES	SAF	Nonforest
1900	40	30	14	44	49	4	32	3
1995	20	13	1	43	77	6	56	0

[a]PP = ponderosa pine (*Pinus ponderosa*); WL = western larch (*Larix occidentalis*); WBP = whitebark pine (*Pinus albicaulis*); LPP = lodgepole pine (*Pinus contorta*); DF = Douglas-fir (*Pseudotsuga menziesii*); ES = Englemann spruce (*Picea englemannii*); SAF = subalpine fir (*Abies lasiocarpa*).

INT-294. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 17 p.

Arno, S. F.; Scott, J.H.; Hartwell, M.G. 1995. Age-class structure of old growth ponderosa pine/Douglas-fir stands and its relationship to fire history. Res. Pap. INT-RP-481. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 25 p.

Arno, S.F.; Simmerman, D.G.; Keane, R.E. 1985. Forest succession on four habitat types in western Montana. Gen. Tech. Rep. INT-177. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 74 p.

Arno, S.F.; Sneck, K.M. 1977. A method for determining fire history in coniferous forests in the Mountain West. Gen. Tech. Rep. INT-42. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 28 p.

Barrett, S. W.; Arno, S.F. 1988. Increment-borer methods for determining fire history in coniferous forests. Gen. Tech. Rep. INT-244. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 15 p.

Brown, J.K. 1995. Fire regimes and their relevance to ecosystem management. In: Proceedings of the Society of American Foresters, 1994 Annual Convention. Bethesda, MD: Society of American Foresters: 171-178.

Brown, J.K.; Arno, S.F.; Barrett, S.W.; Menakis, J.P. 1994. Comparing the prescribed natural fire program with presettlement fires in the Selway-Bitterroot Wilderness. International Journal of Wildland Fire. 4(3): 157-168.

Hartwell, M.; Alaback, P. 1996. Determination of fire-initiated landscape patterns: Restoring fire mosaics on the landscape. In: Hardy, C.C., Arno, S.F., eds. The use of fire in forest restoration. Gen. Tech. Rep. INT-GTR-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 46-48.

Hartwell, M.; Alaback, P. 1997. Comparing historic and present conifer species compositions and structures on forested landscapes of the Bitterroot Front. Contract completion report RJVA-94928 on file at: Intermountain Research Station, Fire Sciences Laboratory, Missoula, Montana. 72 p.

Hill, B.T. 1998. Western national forests: Catastrophic wildfires threaten resources and communities. Testimony before the Subcommittee on Forests and Forest Health, Committee on Resources, House of Representatives, Sept. 28, 1998. U.S. General Accounting Office, T-RCED-98-273. 23 p.

Lackschewitz, K. 1986. Plants of west-central Montana—identification and ecology: annotated checklist. Gen. Tech. Rep. INT-277. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 648 p.

Maser, C.; Anderson, R.G.; Cromack, K. Jr.; Williams, J.T.; Martin, R.E. 1979. Dead and down woody material. In: Thomas, J.W., ed. Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington. Washington, D.C.: U.S. Department of Agriculture, Forest Service. Agriculture Handbook No. 553: chapter 6.

Monnig, E.; Byler, J. 1992. Forest health and ecological integrity in the Northern Rockies. FPM Report 92-7, Second Edition. Northern Region: U.S. Department of Agriculture, Forest Service. 18 p.

Mutch, R.W.; Arno, S.F.; Brown, J.K.; Carlson, C.E.; Ottmar, R.D.; Peterson, J.L. 1993. Forest health in the Blue Mountains: A management strategy for fire-adapted ecosystems. Gen. Tech. Rep. PNW-GTR-310. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 14 p.

O'Laughlin, J.; MacCracken, J.G.; Adams, D.L.; Bunting, S.C.; Blatner, K.A.; Keegan, C.E. III. 1993. Forest health conditions in Idaho: Executive summary. Idaho Forest, Wildlife and Range Experiment Station, Rep. No. 11. University of Idaho, Moscow, Idaho. 37 p.

Stickney, P.F. 1990. Early development of vegetation following holocaustic fire in Northern Rocky Mountain forests. Northwest Science. 64(5): 243-246.

Ecosystem-Based Management at Lower Elevations

Stephen F. Arno

Abstract—Our experience testing ecosystem-based management (EM) treatments in ponderosa pine (*Pinus ponderosa*)/fir (*Abies* spp.) is summarized here. Topics covered include silvicultural treatments, fire application, soils and nutrient considerations, wildlife habitat considerations, associated riparian communities, and treatment of invasive weeds.

The following is a summary of our experience testing ecosystem-based management (EM) treatments in ponderosa pine (*Pinus ponderosa*)/fir (*Pseudotsuga menziesii* and *Abies* spp.) forests and associated riparian communities and montane grasslands. These ecosystems were historically shaped by frequent, low to moderate intensity fires that produced open stands of large fire-resistant pines. They have been greatly altered by exclusion of natural fires for nearly a century and by logging and livestock grazing. They are now being altered in many areas by extensive development of suburban home sites, which greatly complicates application of EM. These ecosystems serve as habitat for a variety of wildlife species and are especially important as winter range because they can provide tree structures for habitat and cover as well as an abundance of forage plants in an environment where snow depths are light to moderate. These ecosystems now serve as critical winter range in many areas due to loss of the historical valley bottom winter range as a result of agricultural and other human developments.

Upland Forests

We have experimented with EM treatments in upland forests ranging from dense ponderosa pine second-growth stands on warm, dry sites to ponderosa pine-western larch (*Larix occidentalis*) stands with understory thickets of Douglas-fir (*Pseudotsuga menziesii*) and grand fir (*Abies grandis*) on moist sites and cool aspects. Some stands were mostly fir thickets although old stumps indicated they were once dominated by ponderosa pine or pine and larch.

The general goal of EM treatments has been to return to some semblance of historical conditions—more open stands dominated by the fire-dependent tree species (ponderosa pine and possibly larch) including large, old trees. In most cases the long-term objective is to maintain this stand condition in perpetuity by periodic treatments to control tree density and species composition and to encourage establishment of new age classes of pine or larch. Douglas-fir and possibly grand fir will tend to increase in dominance and can be controlled to some extent by cutting and burning at intervals of perhaps 20 to 35 years, depending on site productivity.

The initial restoration treatments are especially difficult because the stands are heavily overstocked and under competitive stress and there is often an unusual accumulation of forest fuel which exposes trees to damage from burning. Once this initial situation has been corrected by carefully conducted treatments, the remaining trees should be able to improve in vigor, and conditions for subsequent treatments should become more favorable.

Selecting Areas for Treatment

Anyone who has had experience in EM treatments soon recognizes that it will not be possible to treat all areas that could benefit from it. As a result of a limited work force, money, opportunities for burning, etc., a large proportion of the ponderosa pine zone cannot be treated. Restoration efforts should probably be concentrated in areas where the following factors rate relatively high: ecological need, feasibility of accomplishment, and acceptability from a social and environmental standpoint. Ecological need is relatively high in the ponderosa pine zone because most stands have been heavily altered as a result of past logging and removing natural fires. Feasibility of accomplishment depends on economics and available technology and skills. For instance, steep sites with dense thickets of small trees might be both technologically difficult and very expensive to treat.

Social and environmental acceptability might be heavily constrained by the level of treatment impacts that people are willing to accept—such as visual changes in the forest, or smoke production from treatments. Acceptability might be heavily constrained by environmental regulations. For example, it might be virtually impossible to restore historical conditions in a riparian area because of regulations against cutting and prescribed burning.

Economic Considerations

Areas where treatments can be self-financed have a clear advantage in times of limited budgets. Often the silvicultural harvest that is appropriate for achieving ecological objectives can generate additional funding to pay for other aspects of the treatment (Fiedler and others 1998). Sometimes matching funds for treatment can be obtained from a

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Stephen F. Arno is a retired Research Forester, Fire Effects Research Work Unit, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT.

wildlife-oriented organization such as the Rocky Mountain Elk Foundation or the Wild Sheep Society. Recently The Nature Conservancy has become a sponsor of EM treatments (Reid 1998).

Reference

Reid, Bruce. 1998. A clearing in the forest: new approaches to managing America's woodlands. Nature Conservancy. 48(6): 18-24.

Silvicultural Treatments

Carl E. Fiedler

Abstract—Sustainable, ecologically-based management of pine/fir forests requires silviculturists to integrate several treatments that emulate historic disturbance processes. Restoration prescriptions typically include cleaning or heavy understory thinning, improvement cutting to reduce the proportion of firs, and modified selection cutting to reduce overall stand density, leading to stands that are moderately open, primarily ponderosa pine, uneven-aged, and large-tree dominated.

Several sources of information provide the basis for designing appropriate prescriptions for ecosystem-based management (EM) in pine/fir (*Pinus*/*Pseudotsuga-Abies*) forests. Detailed dendrochronological work in both the Northern Rockies (Arno and others 1995) and the Southwest (White 1985; Covington and Moore 1994), coupled with early photographs and written accounts, provide strong visual, descriptive, and interpretive documentation of common (if not prevalent) pre-European settlement conditions in ponderosa pine (*Pinus ponderosa*) forests. Anderson (1933) and Gruell and others (1982) report that virgin stands in this type were primarily ponderosa pine and uneven-aged or, quoting Meyer (1934), "the typical ponderosa pine forest of the Pacific Northwest is fairly pure, fairly open, and many-aged." Anderson (1933) noted, "Few timber trees west of the Great Plains are better adapted to selective logging than ponderosa pine. Fires, insect depredations, and mortality from old age throughout the past two or three centuries have resulted in uneven-aged stands with a rather irregular distribution of age classes ranging from young seedlings to 600-year-old veterans." Collectively, these sources profile a forest type that was moderately open, uneven-aged, large-tree dominated, and shaped by frequent, low-intensity fires.

The challenge to national forest silviculturists is to integrate a series of silvicultural treatments that will emulate the characteristic disturbance processes in pine forests to produce a semblance of historic structures and conditions—not because they are historic, but because they are sustainable (i.e., vigorous, self-perpetuating, pine-dominated, and at low risk to fire and insects). If silvicultural methods are selected to be compatible with the silvical attributes of ponderosa pine, approximate the nature and intensity of historic disturbances, and develop and sustain the structures that resulted from such disturbances, the path will generally lead to some variant of uneven-aged methods. Historic structures were generally uneven-aged, but not balanced; hence, traditional uneven-aged methods can best serve as points of departure, rather than as specific models for management.

The exact nature of historic conditions in these forests cannot be known, and likely varied substantially from place to place, and at a given place over time. Effects of EM treatments will also vary considerably within a given area on the landscape due to variation in existing stand conditions, application of treatments (particularly fire), and site and terrain features. Because there is no single, discrete "historic condition" does not negate the value of recognizing important features of sustainable conditions—moderate density, large-tree dominance, and primarily ponderosa pine composition—as targets for management. These attributes can be achieved while still allowing considerable latitude in the prescriptive design process to address social, economic, and ecological objectives and concerns. The moderate to low density of historic stands, which was likely both a cause and an effect of the characteristic, low-intensity fires, served several important functions. Moderate density and scattered openings favored regeneration of shade-intolerant ponderosa pine; the associated low fuel levels and frequent burning kept fires generally on the ground and nonlethal; and low density allowed development of large trees with thick bark, which were fire resistant and provided a perpetual seed source to regenerate scattered individuals or groups of trees. Some of this pine regeneration (though few firs) survived the frequent fire gauntlet to develop into large trees, thereby perpetuating the cycle and ensuring sustainability. Target stand conditions that embody these features are moderately open (40 to 90 ft^2/ac), uneven-aged, large-tree dominated [≥20" DBH (Diameter at Breast Height)], and primarily ponderosa pine composition (≥90 percent).

The kinds of silvicultural treatments most appropriate for EM in ponderosa pine/Douglas-fir (*Pseudotsuga menziesii*) forests have seldom been applied, at least in concert, on national forest system lands. For existing stands with irregular or uneven-aged structure, a comprehensive restoration prescription will commonly consist of several treatments: cleaning or heavy understory thinning to break up the continuity of seedling/sapling-sized ladder fuels, a modified selection cutting to reduce overstory density and induce regeneration of ponderosa pine, and an improvement cutting to remove most pole-sized or larger Douglas-fir/true firs and low quality trees of all species not otherwise reserved for snags or other wildlife purposes (Fiedler and others 1999). Alternative treatment regimes for implementing EM in second-growth, even-aged stands are presented by Fiedler (1999).

Stand density following treatment on moderate and drier sites should be less than 50 ft^2/ac to ensure regeneration of shade-intolerant pine, but will vary considerably across the treated area (Fiedler and others 1988). Subsequent harvest entries will occur at 20- to 35-year intervals in the future, when stand density reaches the 75 to 90 ft^2/ac

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Carl E. Fiedler is an Associate Research Professor, School of Forestry, University of Montana, Missoula, MT 59812.

range, depending on site quality, stand conditions, and management objectives. It will be necessary to harvest from about 2 to 5 MBF (thousand board feet per acre) at each entry to achieve the desired reserve density and structure.

In the initial entry, silvicultural treatments will typically need to kill many small trees without commercial value, while removing moderate numbers of medium-sized trees and relatively fewer large trees (usually firs) with commercial value. Fewer trees will need to be killed or removed in subsequent entries, and an increasing proportion of these will be medium- and larger-sized ponderosa pine with substantial commercial value. Leave tree marking is preferred for the initial entry and during the conversion to large-tree dominated conditions since it enables the marker to focus on tree quality, visualize the stand after treatment, and determine residual density more easily (Fiedler and others 1988). One regeneration-related modification of the individual tree selection approach is the creation of patchy openings up to about 1/2 acre by expanding natural openings through judicious marking. Under this approach, each tree is evaluated, with more stringent standards required for leave trees around existing openings. Conversely, occasional groups of larger trees are left intact (or nearly so) to accentuate horizontal and vertical diversity.

Abundant regeneration of ponderosa pine throughout the stand is not required. What is important is that cutting treatments create scattered openings every couple of acres within the stand to induce establishment and early growth of shade-intolerant ponderosa pine. Successional pressure from more shade-tolerant species will also need to be addressed at each entry in most stands, although this pressure should diminish over time if prescribed burning is an integral part of the comprehensive restoration treatment. Fire is especially effective and efficient at killing unwanted fir seedlings (<4.5 ft in height), fire and cutting are both reasonably efficient at killing excess sapling-sized trees, and cutting is generally more efficient for killing trees pole-sized and larger. A primary advantage of cutting, particularly of trees past the sapling stage, is that it allows for the controlled removal of specific trees in terms of number, size, and species to more precisely develop the desired stand condition, whereas fire is a much less selective killing agent. Prescribed burning of sufficient intensity to kill some of the larger trees may well kill the very leave trees desired as part of the future stand. Cutting trees also allows them to be used for timber products, generating income to offset treatment costs.

The initial entry into dense stands with thickets of small trees will likely entail the most severe treatments anticipated in the foreseeable future. Understories in these stands have been developing for decades in the absence of surface fires, and their treatment will generate heavy volumes of slash. Selection cutting in the mid- and upper-canopy and improvement cutting in the fir component will generate additional slash. The combined loading of natural and activity fuels will require well designed prescribed burning of sufficient intensity to reduce hazards and accomplish ecological goals, but not so intense as to damage significant numbers of reserve trees (Harrington, this issue).

Prescribed treatments in the future will entail selection cutting at sufficient levels to induce regeneration of shade-intolerant pine in parts of the stand, increasingly lighter improvement cuttings as the composition of fir decreases, and relatively light cleanings and low thinnings as small-tree density and regeneration are increasingly controlled by prescribed burning, either in concert with, or between harvest entries. Fuel loadings in future entries should be considerably lower than those associated with the initial entry, allowing broader burning windows for application of fire and lower risk of damage to reserve trees.

Air quality regulations, costs, and availability of personnel will likely limit the optimistic burning targets proposed for the future. Cutting treatments can be substituted for some fire effects while other desired effects of burning will not be realized. Even where prescribed burning is generally desirable and feasible, other treatments may be necessary. For example, fire will do little to prepare sites classified within the moister Douglas-fir habitat types for regeneration of ponderosa pine. On these sites, partial mechanical scarification will create conditions more favorable for pine regeneration.

A subtle but fundamental danger of EM is what sometimes appears to be the compromise of silvicultural and ecological principles when developing restoration prescriptions. The propensity to choose thinning-from-below, rather than comprehensive treatments that address all three critical stand characteristics—density, structure, and species composition—is one such example. Reserve density, species composition, and regeneration goals should not be compromised if the target range of conditions is to be achieved and sustained.

References

Anderson I.V. 1933. Application of selective logging to a ponderosa pine operation in western Montana. University of Montana No. 339. 56 p.

Arno, S.F.; Scott, J.H.; Hartwell, M.G. 1995. Age-class structure of old growth ponderosa pine/Douglas-fir stands and its relationship to fire history. Res. Pap. INT-RP-481. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 25 p.

Covington, W.W.; Moore, M.M. 1994. Southwestern ponderosa pine forest structure: changes since Euro-American settlement. Journal of Forestry. 92: 39-47.

Fiedler, C.E.; Becker, R.R.; Haglund, S.A. 1988. Preliminary guidelines for uneven-aged silvicultural prescriptions in ponderosa pine. In: Baumgartner, D.M.; Lotan, J.E., compilers. Ponderosa pine—the species and its management. Symposium Proceedings. 1987 September 29-October 1; Spokane, WA. Pullman, WA: Washington State University Cooperative Extension: 235-241.

Fiedler, C.E.; Keegan, C.E.; Wichman, D.P.; Arno, S.F. 1999. Product and economic implications of ecological restoration. Forest Products Journal. 49: 19-23.

Gruell, G.E.; Arno, S.F.; Carlson, C.E.; Harrington, M.G. 1982. Seventy years of vegetative change in a managed ponderosa pine forest in western Montana—Implications for resource management. Gen. Tech. Rept. INT-130. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 42 p.

Meyer, W.H. 1934. Growth in selectively cut ponderosa pine forests of the Pacific Northwest. Tech. Bull. no. 407. Washington, DC: U.S. Department of Agriculture. 64 p.

White, A.S. 1985. Presettlement regeneration patterns in a southwestern ponderosa pine stand. Ecology. 66: 589-594.

Fire Applications in Ecosystem Management

Michael G. Harrington

Abstract—Decades of fire absence from ponderosa pine/Douglas-fir forests has resulted in overstocked, unhealthy, and severe fire-prone stands requiring management attention. Prescribed fire can be used in three general situations during restoration management. First is when fuel loadings are excessive from either natural accumulation or harvest slash. Second is when dense understory conifers are thinned and burned. Third is when tree cutting is impractical or against policy and, therefore, applied fire may be the only practical option. Maintenance burning should be planned to coincide with future silvicultural activities or to maintain ecological processes.

Fire history records from low elevation ponderosa pine/Douglas-fir (*Pinus ponderosa*/*Pseudotsuga menziesii*) forests clearly indicate the important influence fire has had for centuries as an ecological process (Arno 1988). It functioned as a thinning agent, to stimulate herbaceous and shrubby vegetation, to prepare seedbeds, as a nutrient cycler, and to reduce forest fuels and the severity of inevitable wildfires (Harrington 1996). In the decades of fire absence, most, if not all, of these functions now require attention; therefore, in the overstocked, unhealthy, severe fire-prone stands of today, fire should be considered in the restoration process.

Surface and ground fuels commonly accumulate on these dry sites more quickly than they decompose, resulting in a dead fuel buildup. Additionally, natural regeneration and continuous subsequent growth occurs in the absence of disturbance primarily for shade-tolerant, highly flammable conifers, producing a ladder fuel stratum that can link a surface fire to the crowns of the overstory (Fiedler and others 1996). In most stand conditions with advancing succession and associated health and fire hazard concerns, fire alone is an imperfect, highly variable restoration agent. It is sometimes necessary to use fire alone, but generally some form of prefire thinning is desirable for greater control of stand conditions and fire behavior. With this in mind, there are three general situations in which fire can be considered in restoration management. Two situations include fire preceded by mechanical thinning, one does not.

In the first situation in which rather complete control of tree composition and structure is possible for hazard reduction and health improvement, a thoroughly planned silvicultural operation can be applied. Excess trees of merchantable size can be harvested as described by Fiedler (this proceedings), but resulting fuel loads need to be considered when prescribed burning is planned. If surface and ground fuel loading is high before harvesting, adding new slash may create a fuel condition, which, if burned, could lead to significant tree damage and severe soil impacts. The option to leave these fuels untreated is sometime taken because of the concerns of damaging fire effects and fire control. However, this additional fire hazard remains for years and without burning various fire processes such as small tree thinning, nutrient turnover, plant stimulation, and others are not realized.

If fire application is desired yet fuel loadings appear excessive, several options are available. Much of the potential slash from harvesting can be removed with the logs then piled and burned at safe log landings (Arno and Harrington 1998). Alternately, slash can be concentrated manually on the harvested sites for pile burning under moist conditions prior to broadcast burning.

The prescribed, broadcast burn should be conducted under moderate weather and fuel moisture conditions such that a majority of the fine fuels are consumed but much of the duff and large woody fuels remain. This will lessen the immediate fire hazard but keep fire severity low, minimizing soil heating and injury to stressed overstory, and herbaceous and shrubby understory plants. For example, the most successful EM burns in the Lick Creek Demonstration Area of the Bitterroot National Forest were conducted with fine fuel moistures of 9 percent, duff moistures averaging 50 percent, and large woody fuel moistures about 90 percent. Sixty-fire percent of the litter and small woody fuels were consumed along with 20 percent of the duff. Because adverse plant and soil impacts are caused not only by excessive amounts of fuel consumption, but also by excessive rates of fuel consumption, controlled ignition is important (Kilgore and Curtis 1987).

In the second situation in which harvesting of overstory trees is not possible or desirable, the understory conifers, which make up the ladder fuel component, are most efficiently and effectively removed by cutting followed by either pile burning or broadcast burning (Fiedler and others 1996). Heavy slash fuel elimination is best controlled and least impacting when burning in piles under moist, cool conditions. Prescribed broadcast burning should follow to allow the complete fire process. If slash fuels are not excessive, they could be burned in the prescribed fire along with the natural fuels, as long as ignition is controlled to maintain moderate fire intensity. Where old growth ponderosa pine and western larch (*Larix occidentalis*) are present, raking away the large duff mounds at tree bases may be necessary to reduce cambium and root injury. The efficacy of both pile and broadcast burning of understory ladder fuels will be tested on the Snowbowl Old Growth Stand in the Lolo National Forest. About 650 understory Douglas-fir/acre (Arno and others 1997) were slashed and either piled or scattered beneath old growth ponderosa pine and western larch for burning in the spring of 1999. Two key objectives

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Michael G. Harrington is a Research Forester, Fire Effects Unit, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 8089 Missoula, MT 59807.

are the elimination of the competitive, ladder fuel component and minimizing fire impacts on the old trees.

In the third situation, tree cutting of any kind may be impractical or against policy. These areas might be represented by steep, remote sites, wilderness boundaries, or sites primarily designated for wildlife habitat. Therefore, applied fire may be the only option for reducing severe fire threat and improving forest health through stand density reduction (Kearns 1998). Fire use with a thinning objective is very challenging and is accomplished under a rigid set of environmental and ignition conditions. Because the goal in this type of burning operation is generally to kill certain tree species and sizes and save others, a conservative approach will lead to little more than surface fuel reduction and yet a poorly planned and executed, bold application could lead to excessive damage. Relatively liberal application of fire is generally necessary to sufficiently scorch or consume tree crowns such that mortality of excess trees results. It is important to note that success of this kind of fire treatment leads to a different kind of hazard. As foliage, branches, and stems of the dead trees fall, an inordinate amount of surface fuel results over the next 5 to 10 years. So, even though relief from the ladder fuel hazard may be realized, the threat of a high severity wildfire increases as aerial fuels become surface fuels. Within 10 years another fire treatment would be recommended to reduce the new hazard (Thomas and Agee 1986). Two tests of fire without cutting have been conducted on the Bitterroot National Forest. The hand ignited prescribed burns in dense, Douglas-fir dominated stands resulted in up to 60 percent surface fuel reduction but little stand thinning (data on file, Missoula Fire Sciences Lab).

Whether mechanical thinning is conducted or not, the success of the prescribed underburns is determined by several factors. The amount of dead organic matter consumed is a primary objective that is readily discerned, with too much being as undesirable as too little. In these lower elevation forests with advancing succession, killing the advanced regeneration of the shade tolerant species is also an important goal that is quickly evaluated. Without burning, this cohort will respond to the newly open stand and grow quickly into codominance. This objective must be coupled with the goal of minimizing mortal injury to the favored species and size classes. Several years must pass before a concise appraisal of this goal is possible. A final, easily evaluated goal is the response of native understory vegetation and exotics, which can respond positively or negatively depending on physiology, burn severity, weather, and others.

In these three restoration situations, it is clear that large accumulations of both live and dead forest fuels, within stressed stands are the primary reason for a cautious but deliberate approach to fire application. This approach includes techniques to reduce potentially site-damaging levels of fuels prior to the desired, ecologically sound broadcast burn. Regardless of the effectiveness of these initial fuel and stand density reduction treatments, maintenance burning should be planned to either coincide with future silvicultural activities or be conducted alone to maintain the presence of the ecological fire process in these forest types. Because the stand structure and composition are dynamic, as trees grow and naturally regenerate, and as dead organic matter continues to accumulate, a departure from the desired forest condition occurs. A periodic return of cutting and/or fire simulates the natural fire regime that was primary in sustaining forest health. These regular cycles of purposeful disturbance are typically less challenging to conduct and less costly than initial forest entries because the stand density and fuel amounts are much less. Weather opportunities for maintenance burning are broader and should not conflict with initial fuel management operations.

References

Arno, S.F. 1988. Fire ecology and its management implications in ponderosa pine forests. In: Baumgartner, D.M.; Lotan, J.E., eds. Ponderosa pine—the species and its management. Symposium Proceedings. 1987 September 29-October 1; Spokane, WA. Pullman, WA: Washington State University Cooperative Extension: 133-139.

Arno, S.F.; Harrington, M.G. 1996. The interior west: managing fire-dependent forests by simulating natural disturbance regimes. In: Forest management into the next century: what will make it work? Conference Proceedings. 1997 Nov. 19-21; Spokane, WA. Madison, WI: Forest Products Society: 53-62.

Arno, S.F.; Smith, H.Y.; Krebs, M.A. 1997. Old growth ponderosa pine and western larch stand structures: Influence of pre-1900 fires and fire exclusion. Res. Pap. INT-RP-495. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 20 p.

Fiedler, C.E.; Arno, S.F.; Harrington, M.G. 1996. Flexible silviculture and prescribed burning approaches for improving health of ponderosa pine forests. In: Covington, W.W.; Wagner, P.K., tech. coords. Conference on adaptive ecosystem restoration and management: restoration of Cordilleran conifer landscapes of North America. Conference Proceedings. 1996 June 6-8; Flagstaff, AZ. Gen. Tech Rep. RM-GTR-278. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 69-74.

Harrington, M.G. 1996. Prescribed fire applications: Restoring ecological structure and process in ponderosa pine forests. In: Hardy, C.E.; Arno, S.F., eds. The use of fire in forest restoration. Gen. Tech. Rep. INT-GTR-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 41.

Kearns, M.L. 1998. Big Creek Prescribed Burn. Prescribed Burn Plan on file at: Stevensville Ranger District, Bitterroot National Forest. 26 p.

Kilgore, B.M.; Curtis, G.A. 1987. Guide to understory burning in ponderosa pine-larch-fir forests in the Intermountain West. Gen. Tech. Rep. INT-GTR-233. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 39 p.

Thomas, T.L.; Agee, J.K. 1986. Prescribed fire effects on mixed conifer forest structure at Crater Lake, Oregon. Canadian Journal of Forest Research. 16: 1082-1087.

Soils and Nutrient Considerations

Thomas H. DeLuca

Abstract—Fire suppression has resulted in a buildup of forest litter and an accumulation of organic nitrogen, and a decrease in available potassium. This has changed the historic structure of soils and their nutrient content. Studies at 15 sites in Montana have looked at a wide range of changes in soil productivity following prescribed fire. Results indicate obvious benefits to the soils from reduction in fuel loading through fire, and renewed growth of desirable understory plants.

Restoration of ponderosa pine (*Pinus ponderosa*) forests to more closely resemble pre-1900 stand structures and species compositions generally involves some form of harvest along with use of prescribed fire (Arno and others 1995; Fiedler and others 1996). These Ecosystem-based Management (EM) approaches are aimed at the reduction of surface and ladder fuels that have accumulated as a result of decades of fire suppression. EM is also intended to stimulate herbaceous and shrubby vegetation, to prepare mineral-soil seedbeds, and to kill undesirable conifers (see Harrington, this issue). Although historic stand structures can be quickly envisioned following these prescriptive treatments, there is only limited understanding of how these treatments influence soil processes and nutrient availability and how these influences compare to those of the historic disturbance regime of frequent, low-intensity fires.

Ponderosa pine and Douglas-fir (*Pseudotsuga menziesii*) forests of the inland Northwest commonly accumulate little inorganic nitrogen (N) in the mineral soil because of slow decay rates and rapid uptake by plants and microorganisms. These forests are generally assumed to contain suboptimal N levels (Mandzak and Moore 1994). This N limitation is thought to be due to the accumulation of organic matter composed of low N woody residues within the forest floor and mineral soil of coniferous forests, resulting in little or no N release from the organic reservoir that houses soil N (Keeney 1980). Fire suppression has resulted in a buildup of forest litter (Covington and Sackett 1993), accumulation of inhibitory compounds (terpenoids) associated with pine needles (White 1986), and accumulation of N in living forest biomass (Hungerford and others 1991). Many forests of the inland Northwest are also considered to be potassium (K) deficient, depending upon the type of geologic material from which the soils formed (Mandzak and Moore 1994).

The significance of low N and other aspects of apparent infertility in these forests are not clear. We do know that historically many (perhaps most) of these forests were maintained in multi-aged stands, which included very large long-lived ponderosa pines, maintained by frequent low-intensity fires. It is likely that there were relatively small quantities of duff, humus, and coarse woody debris associated with the historic conditions. Annual precipitation and available moisture in these ecosystems are so low that, in some regions of the world, areas having comparable moisture do not support large trees. Perhaps these semiarid ponderosa pine ecosystems functioned naturally at low levels of certain nutrients.

Wildfire and prescribed fire in ponderosa pine forests generally result in an increase in plant available N due to removal of forest floor (Covington and Sackett 1992), volatilization of terpenoids (White 1986), denaturation of organic N compounds, and killing of soil microbial biomass (Hernandez and others 1997). The resulting release of inorganic N immediately following burning of ponderosa pine forests has been reported in numerous papers (Kovacic and others 1986; Covington and Sackett 1992; Monleon and others 1997). This increase in immediately available N is considered to improve N fertility in ponderosa pine forests. However, productivity of ponderosa pine forests may decline following first-entry fire treatments as a result of root kill (Grier 1989) or perhaps due to a reduction in N mineralization potential (Monleon and others 1997).

We have been investigating the effect of forest restoration efforts (harvest with and without prescribed burning) as well as wildfire with and without previous prescribed fire on nutrient availability, microbial activity, and soil organic matter quantity and quality. Studies have been carried out at 15 sites in western Montana, including the Lick Creek Demonstration Area on the Bitterroot National Forest and at the University of Montana's Lubrecht Experimental Forest.

Our investigations have demonstrated that prescribed fire following selection or shelterwood harvest results in a short term increase in mineral N followed by a long term decline in available N (DeLuca and Zouhar 2000; Newland and DeLuca 2000). The higher severity fires (such as the 1994 Willow Creek Wildfire on the Bitterroot National Forest) result in the greatest N loss from the ecosystem (Choromanska and DeLuca 2000). When prescribed fire precedes a wildfire, the N loss is lower than if the site experiences wildfire alone. These declines in available N are paralleled by a decrease in microbial activity wherein microbial biomass and basal respiration rates are reduced following fire and are reduced to the greatest degree on high severity fire sites.

The connection between a reduction in mineralizable N levels following fire and an increase in site productivity may seem difficult to reconcile; however, it must be stressed that we do not have a historic reference site with which to compare the fire treatments. The composition and function of understory plants may play an important role in maintaining long term productivity of sites with low levels of

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Thomas H. DeLuca is a Professor, School of Forestry, University of Montana, Missoula, MT 59812, e-mail: thd@forestry.umt.edu

mineralizable N. Sites with well developed understory communities in ponderosa pine forests in central Oregon showed increased long term growth of trees, total organic matter, and microbial biomass compared to sites in which understory vegetation had been excluded for 35 years (Busse and others 1996). Fire exclusion has clearly altered understory plant communities. In our studies, N fixing plant species were in low numbers on all sites, but were more common on sites exposed to fire and most common on sites that had been repeatedly opened by harvest prior to reintroduction of fire.

Our studies suggest that ponderosa pine forests with frequent low-intensity fires may have once had higher densities of N-fixing plants, including legumes (e.g., lupine [*Lupinus* spp.]) or actinorrhizal species (e.g., bitterbrush [*Purshia tridentata*]) (Newland and DeLuca 2000). The paucity of remaining old growth stands and the fact that these have been altered by fire suppression make repeatedly opened sites in ponderosa pine forests the best representation of historic forest structure in western Montana (Arno 1996). Efforts to restore historic ecological function in these forests may allow managers to increase the density of N-fixing plants while meeting other management objectives. It is important to learn more about the contribution of N-fixing plants to the N cycle of western Montana forests. If N-fixing plants become more common with increasing disturbance and available soil N becomes lower, input of N from N-fixing plants may become very important in maintaining forest productivity.

Obvious benefits realized from prescribed fire include a reduction in fuel loading, thereby reducing the potential for a high severity wildfire that would lead to (1) greater losses of N, phosphorus, and sulfur, (2) greater microbial mortality, and (3) greater potential for post-fire erosion events (Hernandez and others 1993). Such treatments also allow for growth of understory plants that had been out-competed and excluded as a result of eliminating frequent fires. These understory species may directly or indirectly influence nutrient availability.

At first glance, a decrease in total mineralizable N in forests that have generally been considered N deficient may seem like a negative impact of re-introducing fire. However, the reduced stand density following fire has lower N demand, and the decline in available N may actually have several positive effects, such as:

1. Reduced available N and increased or static concentrations of exchangeable K resulting in a more balanced ratio of N:K, thereby resulting in lower susceptibility to disease or insect attack (Mandzak and Moore 1994).

2. Reduced levels of mineralizable N resulting in greater ability of native N fixing species to colonize sites following fire (Leach and Givnish 1997), thus providing a more labile form of N compared to the recalcitrant N associated with duff or resident soil organic matter.

3. Reduced levels of mineralizable N may decrease the ease with which non-native plant species compete with native species (Wedin and Tilman 1996).

Further studies are being conducted on the Bitterroot National Forest to assess some of the interactions of fire and N. Those studies are investigating the following effects of fire on:

1. N turnover rates and plant uptake rates of N, and how that may influence productivity.

2. N:K and how this influences root phenolic concentrations.

3. The change in understory vegetation (from ericaceous shrubs to graminoids) and how this change in plant species influences soil organic matter quality as it relates to nutrient turnover.

References

Arno, S.F.; Harrington, M.G.; Fielder, C.E.; Carlson, C.E. 1995. Restoring fire-dependent Ponderosa pine forests in Western Montana. Restoration and Management Notes. 13: 32-36.

Arno, S.F. 1996. The concept: restoring ecological structure and process in ponderosa pine forests. In: Hardy, C.E.; Arno, S.F., eds. The use of fire in forest restoration. Gen. Tech. Rep. INT-GTR-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 37-38.

Busse, M.D.; Cochran, P.H.; Barrett, J.W. 1996. Changes in ponderosa pine site productivity following removal of understory vegetation. Soil Science Society of America Journal. 60: 1614-1621.

Choromanska, U.; DeLuca, T.H. 2000. Prescribed fire alters the effect of wildfire on soil biochemical properties in a ponderosa pine forest. Soil Science Society of America Journal: In Press.

Covington, W.W.; Sackett, S.S. 1992. Soil mineral nitrogen changes following prescribed burning in Ponderosa pine. Forest Ecology and Management. 54: 175-1991.

Diaz-Ravina, M.; Prieto, A.; Baath E. 1996. Bacterial activity in a forest soil after heating and organic amendments measured by thymadine and leucine incorporation techniques. Soil Biology & Biochemistry. 28: 419-426.

DeLuca, T.H.; Zouhar, K. 2000. Effects of selection harvest and prescribed fire on the soil N status of ponderosa pine forests. Forest Ecology and Management: In Press.

Entry, J.A.; Stark, N.M.; Lowenstein, H. 1986. Effect of timber harvesting on microbial biomass fluxes in a northern Rocky Mountain forest soil. Canadian Journal of Forest Research. 16: 1076-1081.

Fernandez, I.; Cabaneiro, A.; Carballas, T. 1997. Organic matter changes immediately after a wildfire in an Atlantic forest soil and comparison with laboratory soil heating. Soil Biology & Biochemistry. 29: 1-11.

Fiedler, C.E.; Arno S.F.; Carlson, C.E.; Harrington, M.G. 1992. Management prescriptions for restoring biodiversity in Inland Northwest Ponderosa pine-fir forests. Northwest Environmental Journal. 8: 211-213.

Grier, C.C. 1989. Effects of prescribed springtime underburning on production and nutrient status of a young ponderosa pine stand. In: Tecle, A.; Covington, W.W.; Hamre, R.H., tech. coords. Multiresource Management of Ponderosa Pine Forests: Proceedings of the Symposium; 14-16 November 1989; Flagstaff, AZ. Gen. Tech. Rep. RM-185. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 71-76.

Hernandez, T.; Garcia, C.; Reinhardt, L. 1993. Short-term effect of wildfire on the chemical, biochemical, and microbiological properties of Mediterranean pine forest soils. Biology and Fertility of Soils. 25: 109-116.

Hungerford, R.D.; Harrington, M.G.; Frandsen, W.H.; Ryan, K.C., Niehoff, G.J. 1991. Influence of fire on factors that affect site productivity. In: Harvey, Alan E.; Neuenschwander, Leon F., comps. Proceedings — Management and Productivity of Western-Montane Forest Soils. 1990 April 10-12; Boise, ID. Gen. Tech. Rep. INT-280. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 32-50.

Jurgensen, M.F.; Harvey, A.E.; Graham, R.T.; Page-Dumroese, D.S.; Tonn, J.R.; Larsen, M.J.; Jain, T.B. 1997. Impacts of timber harvesting on soil organic matter, productivity, and health of Inland Northwest forests. Forest Science. 43: 234-251.

Keeney, D.R. 1980. Prediction of soil nitrogen availability in forest ecosystems: A literature review. Forest Science. 26: 159-171.

Kovacic, D.A.; Swift, D.M.; Ellis, J.E.; Hakonson, T.E. 1986. Immediate effects of prescribed burning on mineral soil nitrogen in Ponderosa pine of New Mexico. Soil Science. 141: 71-76.

Leach, M.K.; Givnish, T.J. 1996. Ecological determinants of species loss in remnant prairies. Science. 273: 1555-1558.

Mandzak, J.M.; Moore, J.A. 1994. The role of nutrition in the health of inland western forests. Journal of Sustainable Forestry. 2: 191-210.

Monleon, V. J.; Choromack, K.; Landsberg, J.D. 1997. Short- and long-term effects of prescribed underburning on nitrogen availability in ponderosa pine stands in central Oregon. Canadian Journal of Forest Research. 27: 369-378.

Newland, J.A.; DeLuca, T.H. 2000. Influence of fire on native nitrogen fixing plants and the soil N status of ponderosa pine forests in western Montana. Canadian Journal of Forest Research. 30: 274-282.

Wedin, D.A.; Tilman, D. 1996. Influence of nitrogen loading and species composition on the carbon balance of grasslands. Science. 274: 1720-1723.

White, C.S. 1986. Effects of prescribed fire on rates of decomposition and nitrogen mineralization in a Ponderosa pine ecosystem. Biology and Fertility of Soils. 2: 87-95.

Wildlife Habitat Considerations

Helen Y. Smith

Abstract—Fire, insects, disease, harvesting, and precommercial thinning all create mosaics on Northern Rocky Mountain landscapes. These mosaics are important for faunal habitat. Consequently, changes such as created openings or an increase in heavily stocked areas affect the water, cover, and food of forest habitats. The "no action" alternative in ecosystem management of low elevation ponderosa pine/Douglas-fir (*Pinus ponderosa/Pseudotsuga menziesii*) forests needs the same careful consideration as other alternatives because the consequences may be detrimental to some wildlife habitats. Suitable management should provide habitat heterogeneity necessary for a diversity of wildlife. A database of helpful information for managers in discussed.

Water, cover, and food are basic needs for wildlife. The availability of these resources changes with the seasons, especially in areas where winters can be severe such as the Northern Rocky Mountains. The physiological demands of wildlife also change with the seasons. It is in the low elevation, ponderosa pine/Douglas-fir (*Pinus ponderosa/Pseudotsuga menziesii*) forests that many animals seek winter habitat because snow depths tend to be low to moderate, both forage and cover are generally available, and temperatures and winds are moderated by the forest. Ample food and water are often the most important needs for wildlife survival. Generally, habitat quality for different animal species is based on vegetative composition and structure (Thomas and others 1979). The structure and composition of the forest affects food availability and cover. For example, herbivores are generally aided by openings in the forest where forage tends to be more abundant, yet they need adequate cover in fairly close proximity. The herbivores, in turn, provide prey for carnivores. Bird habitat is very diverse; different bird species are nectivorous, frugivorous, herbivorous, insectivorous, carnivorous, or omnivorous. Within these diet groupings, there is further separation according to how birds obtain their food (Ehrlich and others 1988).

Sources of water generally remain in the same place on the landscape, but the availability of food and cover is more obviously affected by management actions in our forests. Forest structure and potential wildlife habitat can be thought of in terms of landscape mosaics—patches composed of different vegetation types or the same vegetation type in different stages of succession or development. Mosaics do not necessarily have distinct edges. Another way of looking at wildlife habitat quality is the concept of habitat heterogeneity, which Morrison and others (1998) define as "the degree of discontinuity in environmental conditions across a landscape for a particular species." They go on to say that "environmental conditions can include vegetation structure and composition, as well as more dynamic flows of energy, nutrients, resources, and fluids (water and air)." Some degree of discontinuity is generally positive, but at some level (which is different for each species), heterogeneity becomes habitat fragmentation.

Forces of nature such as fire, forest insect and disease outbreaks, and wind help to create vegetational mosaics on the landscape, which are important for maintaining faunal diversity. Silvicultural activities, including commercial harvesting, precommercial thinning and the use of fire, also create vegetational mosaics. As with any management action, ecosystem-based management (EM) treatments may have contrasting effects on different wildlife species. Habitat improvements for some species may lead to a decrease in habitat quality for others. This paradox is just one example of the many issues surrounding land management decisions today. Any type of action, from precommercial thinning to fire suppression, affects vegetative structure and composition. Likewise, "no action" alternatives also have effects on wildlife habitat.

Effects of management activities on wildlife habitat need to be anticipated and recognized. For example, a more open understory tends to attract more ground feeding birds such as northern flickers (*Colaptes auratus*), dark-eyed juncos (*Junco hyemalis*) or birds that favor open woodlands such as western bluebirds (*Sialia mexicana*), mountain bluebirds (*S. currucoides*), or blue grouse (*Dendragapus obscurus*) while displacing some canopy-feeders such as ruby-crowned kinglets (*Regulus calendula*) and solitary vireos (*Vireo solitarius*) (Gruell and others 1982). Standing snags are important for a variety of wildlife species. One species of interest is the flammulated owl (*Otus flammeolus*), which has quite diverse habitat needs. In western Montana, they require large ponderosa pine trees and snags, understory tree thickets, and grassy openings to meet their nesting, roosting, and feeding needs (Wright 1996). These diverse requirements are an example of the complicated landscape mosaic or habitat heterogeneity needed by one species. Most silvicultural activities will reduce cover of standing trees to some degree, but may increase coarse woody debris in the form of downed logs or standing snags. Coarse woody debris, once largely unrecognized, is now recognized as a valuable component of healthy functioning ecosystems (Harmon and others 1986).

Much research has been conducted regarding how management activities will affect plant composition. One source of information is the Fire Effects Information System (**http://www.fs.fed.us/database/feis/**), which has writeups on many different species of plants and animals with regard to fire ecology. For example, one can look up grizzly bears (*Ursus arctos*) and read a synopsis of published information regarding how fire affects bear habitat. A database of this kind is very useful, but managers must realize that the

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Helen Y. Smith is an Ecologist, Fire Effects Unit, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 8089, Missoula, MT 59807.

writeups may lag behind current literature a bit because they are updated on a revolving schedule. Other sources of information are decision-pathway models that have been developed to predict effects of land management actions on vegetational composition. Other types of models look at habitat effectiveness. An example is the habitat effectiveness model that has been developed for winter habitat for Rocky Mountain elk (*Cervus elaphus nelsonii*) in the Blue Mountains of Oregon (Thomas and others 1988). The creators of this model identified the following four key attributes affecting habitat quality: (1) size and spacing of cover and forage areas, (2) density of roads traveled by vehicles, (3) quantity and quality of forage, and (4) cover quality (Thomas and others 1988). By comparing current with estimated conditions after treatment, an indication of effects on habitat quality can be assessed. Caution must be used when working with models developed or information gained from outside the management area of interest.

The task of juggling the needs of cover with food production is often a major challenge of wildlife habitat management. McConnell and Smith (1970) found that as canopy closes, the amount of grass, forb and shrub vegetation decreased in an eastern Washington ponderosa pine stand. As seen in EM treatments that combined partial overstory removal followed by burning at Lick Creek (Bitterroot National Forest, MT) there was a small decline in the number of willow (*Salix scouleriana*) plants and a greater decline in the number of bitterbrush (*Purshia tridentata*) plants, but overall vigor of the remaining plants increased (Bedunah and others 1999). These shrub species as well as other important browse species for herbivores such as serviceberry (*Amelanchier alnifolia*), elderberry (*Sambucus* spp.), mountain ash (*Sorbus* spp.), and buffaloberry (*Shepherdia canadensis*) often respond well to opening the overstory and broadcast burning (Hillis 1986). Huckleberry (*Vaccinium* spp.) shrubs also tend to be more productive in burned versus unburned sites (Zager 1980).

An important consideration regarding EM treatments and increased food availability is that treated areas tend to attract large numbers of ungulates, especially to improved winter range. This, in turn, can be detrimental to the food resource due to over-browsing. This type of impact was observed at the Lick Creek research study area (Arno 1999). One possible solution is to have more or larger areas treated to help disperse the animals across the landscape.

Our upland ponderosa pine/Douglas-fir forests are generally more contiguous with less variability in vegetative structure and composition across the landscape than occurred historically (Arno 1988). The "no-action" alternative in forest management (which usually attempts to suppress all fires) does nothing to mitigate these conditions and has the potential to set the stage for more widespread events like large wildfires or insect and disease outbreaks. These, in turn, can be detrimental for some wildlife habitat needs. The application of EM treatments can help reduce wildfire hazards and recycle nutrients, while retaining some cover and diversifying wildlife habitat. It is impossible to manage each parcel of land for every plant and animal species, but with careful management we can help to provide landscape mosaics and suitable habitat heterogeneity necessary for a great diversity of wildlife.

References

Arno, S.F. 1988. Fire ecology and its management implications in ponderosa pine forests. In: Baumgartner, D.M.; Lotan, J.E., eds. Ponderosa pine — the species and its management. Symposium Proceedings. 1987 September 29-October 1; Spokane, WA. Pullman, WA: Washington State University Cooperative Extension: 133-139.

Arno, S.F. 1999. Undergrowth response, Shelterwood Cutting Unit. In: Smith, H.Y.; Arno, S.F., eds. Eighty-eight years of change in a managed ponderosa pine forest. Gen. Tech. Rep. RMRS-GTR-23. Ogden, UT: U.S. Department of Agriculture, Rocky Mountain Research Station: 36-37.

Bedunah, D.J.; Harrington, M.G.; Ayers, D.M. 1999. Antelope bitterbrush and Scouler's willow response, Shelterwood Cutting Unit. In: Smith, H.Y.; Arno, S.F., eds. Eighty-eight years of change in a managed ponderosa pine forest. Gen. Tech. Rep. RMRS-GTR-23. Ogden, UT: U.S. Department of Agriculture, Rocky Mountain Research Station: 40-43.

Ehrlich, P.R.; Dobkin, D.S.; Wheye, D. 1988. The Birder's Handbook. Simon & Schuster Inc., New York, New York. 783 p.

Gruell, G.E.; Schmidt, W.C.; Arno, S.F.; Reich, W.J. 1982. Seventy years of change in a managed ponderosa pine forest in western Montana—Implications for resource management. Gen. Tech. Rep. INT-130. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 42 p.

Harmon, M.E.; Franklin, J.F.; Swanson, F.J.; [and others]. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research. 15: 133-302.

Hillis, M. 1986. Enhancing grizzly bear habitat through timber harvesting In: Contreras, G.P.; Evans, K.E., comps. Proceedings—Grizzly bear habitat symposium. 1985 April 30-May 2; Missoula, MT. Gen. Tech. Rep. INT-207. Ogden, UT: U.S. Department of Agriculture, Forest Service. Intermountain Research Station: 176-179.

Leopold, A. 1933. Game management. Charles Scribner & Sons, New York. 481 p.

McConnell, B.R.; Smith, J.G. 1970. Response of understory vegetation to ponderosa pine thinnings in eastern Washington. Journal of Range Management. 23(3): 208-212.

Morrison, M.L.; Marcot, B.G.; Mannan, R.W. 1998. Wildlife-habitat relationships: Concepts and applications. 2nd Edition. University of Wisconsin Press. 458 p.

Thomas, J.W.; Leckenby, D.A.; Henjum, M.; [and others]. 1988. Habitat-effectiveness index for elk on Blue Mountain winter ranges. Gen. Tech. Rep. PNW-GTR-218. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 28 p.

Thomas, J.W.; Miller, R.J.; Maser, C.; [and others]. 1979. Plant communities and successional stages In: J.W. Thomas, tech. ed. Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington. 1979. U.S. Department of Agriculture, Forest Service. Agriculture Handbook 553.

Wright, V. 1996. Multi-scale analysis of flammulated owl habitat use: Owl distribution, habitat management, and conservation. Missoula, MT: University of Montana. 91 p. Thesis.

Zager, P.E. 1980. The influence of logging and wildfire on grizzly bear habitat in northwestern Montana. Missoula, MT: University of Montana. 131 p. Dissertation.

Associated Riparian Communities

Colin C. Hardy
Robert E. Keane
Michael G. Harrington

Abstract—Some 100 years of fire exclusion in the Interior Northwest has resulted in riparian areas dominated by dense thickets of shade-tolerant trees. If former, more open conditions could be restored, these habitats could once more support a more diverse bird community. Efforts toward this at two study sites are described.

The following excerpt was taken from: Hardy, C. C.; Keane, R. E.; Harrington, M. G. 1999. Restoration in northwest interior forests. In: Transactions of the 64th North American wildlife and natural resources conference; 1999 March 26-30; San Francisco, CA. Washington, DC: Wildlife Management Institute: 117-138.

Many riparian areas associated with ponderosa pine (*Pinus ponderosa*) zones common to the interior Northwest historically experienced low-intensity fires as frequently as two to five per century—the frequent, low-severity fire regime. Now after 70 to 100 years of fire exclusion, most riparian areas in the ponderosa pine zone are dominated by dense thickets of shade-tolerant trees, sometimes to the extent of a virtual monoculture of grand fir (*Abies grandis*). In their historic conditions, these riparian habitats were dominated by very large, open-growing pine and larch (*Larix occidentalis*) with numerous species of hardwood trees and fruit-bearing shrubs. If these conditions can be restored, these habitats can again support some of the most diverse bird communities in North America. For example, a recent examinations of riparian habitat for birds done on the Bitterroot National Forest in western Montana showed that species richness was 29 percent greater in deciduous riparian patches than in surrounding pine-fir forest, and 44 percent greater than in coniferous riparian areas lacking the seral, deciduous understory (Wheeler and others 1997). The current trends toward increasing losses of this historically diverse, fire-dependent riparian habitat is a serious issue with respect to Neotropical songbirds, whose habitats in major valleys are no longer suitable due to nest predation by cowbirds (*Molothrus ater*) associated with agriculture and development.

Restoration treatments have been implemented on two small streams in western Montana—Larry Creek and Rock Creek. The management goal is to create conditions that will allow a return of seral vegetation and to reduce the risks of severe wildfire and insect or disease epidemics. The projects are demonstrating two feasible methods for removing most of the dense conifer understory.

At each of the two riparian study sites, three treatments are being compared: mechanical thinning alone, mechanical thinning followed by understory burning, and an untreated control. In the two thinning treatments, most of the small, shade-tolerant trees that make up the dense thickets were cut and removed to reduce competition and open up the site to sunlight and precipitation. In addition, many of the shade-tolerant overstory trees were removed while the seral ponderosa pine and western larch were left. To minimize soil impacts, all tree skidding was done with a farm tractor equipped with a harvesting winch over frozen, snow-covered ground. In the burn treatment, a fuel bed of grand fir saplings was left to allow a high level of control over the prescribed burn. The purpose of the burn was to stimulate herbaceous and shrubby vegetation and to create mineral soil microsites suitable for seedbeds. A systematic survey of overstory and understory trees and understory vegetation, as well as the physical and chemical characteristics of the stream, was made before treatments and will continue for several years after treatments.

Reference

Wheeler, F. J.; Redman, T. S.; Tewksbury, J. J. 1997. Montane riparian habitat for birds: islands of diversity, retreats for survival. In: Natural Resource News. Blue Mountain Natural Resource Institute, LaGrande, OR. Spring 1997: 10-11.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Colin C. Hardy is a Supervisory Research Forester, Robert E. Keane is a Research Ecologist, and Michael G. Harrington is a Research Forester, Fire Effects Unit, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 8089, Missoula, MT 59807.

Restoration of Native Plant Communities Infested by Invasive Weeds—Sawmill Creek Research Natural Area

Peter Rice

Abstract—Invasive alien weeds established themselves on the Sawmill Creek Research Natural Area, harming elk feeding grounds and threatening the integrity of the native pant community. Management enacted herbicide control over several growing seasons, resulting in greater elk winter forage on study plots. Monitoring the long-term effects of herbicide as a restoration tool continues.

Sawmill Creek was designated a Research Natural Area (RNA) in 1992 to provide superior examples of fescue grassland and open canopy forest habitat types. However, a number of invasive alien plants had become established in the RNA. A 1994 weed mapping effort confirmed that spotted knapweed (*Centaurea maculosa*) had spread throughout almost the entire 160 acres of montane grasslands within the RNA. Small colonies of the noxious weeds leafy spurge (*Euphorbia esula*), dalmatian toadflax (*Linaria dalmatica*), Saint Johnswort (*Hypericum perforatum*), and sulfur cinquefoil (*Potentilla recta*) were scattered throughout the grassland and forest habitat types. The continued expansion of these exotics threatened the integrity of native plant communities and the value of the site as elk (*Cervus elaphus*) winter range. Working in conjunction, personnel from the Bitterroot National Forest and the University of Montana have written an integrated vegetation management plan. The management goals of the plan were to restore the native plant communities and enhance the value of the site for elk winter range. Herbicides, biocontrol insects, changes in access and use patterns, limited hand digging, and finally reintroduction of fire are being employed to control the weeds and revitalize native species. The control objective for spotted knapweed was to suppress its abundance within the RNA. The other noxious weed species, which still had infestations of limited size, were targeted for eradication or containment. An extensive plant community monitoring system, with replicated plots and transects, was installed on the RNA. The purpose of the monitoring is to provide scientific documentation of the results of these weed control and grassland restoration techniques being implemented at an operational scale.

Earlier small plot work using herbicides to suppress spotted knapweed in bunchgrass and open canopy forest habitat types had suggested that significant conservation benefits could be realized by appropriate use of herbicides. Tordon (picloram), Transline (clopyralid), and Curtail (clopyralid plus 2,4-D) had been applied to replicated experimental plots at four sites in western Montana. Plant community response was measured for an eight-year period. By the third year after spraying, herbicide plots averaged 47 percent greater elk winter forage than the no-spray check plots (Rice and others 1997a). By three growing seasons post-spray, all herbicide treated plots had plant community diversity as high or higher than no-spray check plots (Rice and others 1997b). A second round of herbicide treatments to control recently emerged knapweed was made following the third year post-spray measurements. Plant community diversity was still maintained after eight years even with the second herbicide application. A detailed comparison of the community composition of the sprayed plots with the original Mueggler and Stewart (1980) data sets that define these specific bunchgrass habitat types revealed that the sprayed plots were more similar to the potential natural communities than the no-spray checks (Rice and Toney 1998).

Test plots on the RNA sprayed with Tordon herbicide in the fall of 1996 confirmed that the Sawmill native bunchgrass communities, including the native wild flowers, would also respond favorably to release from the constant competition with spotted knapweed. One hundred and sixty acres of spotted knapweed infested grasslands were broadcast sprayed by ATV, truck, and backpack sprayers in the fall of 1998. Tordon was used in the open grasslands and Transline in the ecotones with the forest habitat types. Starting in 1996, moths (*Agapeta zoegana*) and weevils (*Cyphocleonus achates*) whose larvae bore out the roots of spotted knapweed were released on adjoining private land and portions of the RNA that were not suitable for ground based herbicide applications. It is intended that these insects will provide long-term biological suppression of knapweed.

An environmental impact statement (EIS) is currently required for aircraft application of herbicides on Forest Service lands, while a ground based treatment can be implemented following an environmental assessment (EA). Most of the Sawmill site was treated using a spray boom mounted on an ATV. Some areas adjacent to the roads were treated by hose reel and handgun from a truck, and a backpack sprayer was used on a few spots inaccessible to the ATV. Although an EA can be completed at lower cost than an EIS, as was the case with the Sawmill project, there are significant cost savings in helicopter application. Spraying cost in this rugged steep terrain was $110 per acre for ground application. A helicopter application would have cost only $20 to $30 per acre.

Helicopter spraying has important conservation and environmental advantages over ground based application in

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Peter Rice is a Research Associate, Division of Biological Sciences, University of Montana, Missoula, MT 59812.

addition to lower per acre treatment costs. Aircraft operator exposure to herbicide residues is lower than for ground vehicle and backpack sprayer crews. Large blocks can be sprayed very quickly when weather conditions and plant growth stages are optimal for spraying. A narrow window of opportunity with the most favorable conditions can be used to reduce drift, maximize efficacy on target weeds, and minimize herbicide injury to desirable plants. Normal use of the site by wildlife and recreationists is disrupted less by compressing the duration of treatment activities. Sawmill could have been helicopter sprayed in less than half a day. The ground-based work took 36 days.

Elk are quickly attracted to the enhanced grazing conditions in the herbicide sprayed areas of knapweed degraded winter ranges. The elk exhibit a strong early spring selection preference for these newly vigorous bunchgrasses. If too small an area is sprayed, the concentration of elk may negate some of the benefit of treatment and slow recovery of the native plants. Cost effective treatment of larger blocks should help disperse grazing elk during the initial years of recovery of the bunchgrass communities from competition with knapweed.

The Sawmill RNA Project demonstrates that appropriate use of herbicides can provide clear benefits in the restoration of native plant communities and the enhancement of the wildlife value of montane grasslands. The Ravalli County Weed District, adjacent private land owners, Rocky Mountain Elk Foundation, Stewart Spraying, Western Agricultural Research Center, University of Montana, Rocky Mountain Research Station, and the Bitterroot National Forest cooperated in the design, funding, and implementation of this restoration project. Now that the weeds are suppressed it is possible to reintroduce fire to both the grassland and forested areas of the site without increasing the weed problem. Response monitoring will continue beyond the year 2000. Experience gained on this project can serve as a model for the restoration of other high conservation value sites that are being degraded by invasive weeds.

References

Rice, P.M.; Toney, J.C. 1998. Exotic weed control treatments for conservation of fescue grassland in Montana. Biological Conservation. 85: 83-95.

Rice, P.M.; Toney, J.C.; Bedunah, D.J; Carlson, C.E. 1997a. Elk winter forage enhancement by herbicide control of spotted knapweed. Wildlife Society Bulletin. 25(3): 627-633.

Rice, P.M.; Toney, J.C.; Bedunah, D.J.; Carlson, C.E. 1997b. Plant community diversity and growth form responses to herbicide applications for the control of *Centaurea maculosa*. Journal of Applied Ecology. 34: 1397-1412.

Rice, P.M.; Toney, J.C. 1996. Plant population response to broadcast herbicide applications for spotted knapweed control. Down To Earth. 51(2): 14-19.

Rice, P.M.; Bedunah, D.J.; Carlson, C.E. 1992. Plant community diversity after herbicide control of spotted knapweed. Res. Pap. INT-460. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 7 p.

Ecosystem-Based Management in the Lodgepole Pine Zone

Colin C. Hardy
Robert E. Keane
Catherine A. Stewart

Abstract—The significant geographic extent of lodgepole pine (*Pinus contorta*) in the interior West and the large proportion within the mixed-severity fire regime has led to efforts for more ecologically based management of lodgepole pine. New research and demonstration activities are presented that may provide knowledge and techniques to manage lodgepole pine forests in the interior West. First, at the stand and watershed levels, a current application of a suite of restoration treatments to lodgepole pine stands within a watershed in central Montana is discussed. Second, a Bitterroot Ecosystem Management Research Project (BEMRP) study is presented that characterized landscape and patch dynamics in lodgepole pine forests at a coarser spatial resolution. Various landscape metrics for quantification of the range of variation in aerial extent of cover type and structural stage categories were used, and the implications for ecosystem management are discussed.

The subalpine lodgepole pine forest type is estimated to cover about 15 million acres in the western United States and a much larger area (nearly 50 million acres) in western Canada (Lotan and Critchfield 1990). Lodgepole pine is the fourth most extensive timber type west of the Mississippi River and is the third most extensive in the Rocky Mountains. Its range extends from 35° latitude to the Yukon at 65° latitude, and longitudinally from the Pacific coast to the Black Hills of South Dakota. The adaptations of lodgepole pine to severe, stand replacement fire—in particular its serotinous cones—has long been acknowledged. Less well known is that lodgepole pine forests also burned in low- to mixed-severity fire, often creating two-aged stands and variable patterns across the landscape (Agee 1993; Arno 1980; Barrett and others 1991). Numerous studies in the interior Northwest have documented the intricate mosaic patterns of historical fires in lodgepole pine forests (Arno and others 1993; Barrett 1993; Barrett and others 1991). Newer studies are looking more closely at the details of these patterns and their implications for management. These studies are being used as a basis for designing and refining silviculture and prescribed fire treatments in national forests of the Northern Rocky Mountains.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Colin C. Hardy is a Supervisory Research Forester and Robert E. Keane is a Research Ecologist, Fire Effects Research Work Unit, Rocky Mountain Research Station, USDA Forest Service, Missoula, MT. Catherine A. Stewart is the Fire Ecologist, Lolo National Forest, Northern Region, USDA Forest Service, Missoula, MT.

In the past, clearcutting and broadcast burning of lodgepole pine forests was considered to be economically efficient and conducive to regeneration. These treatments roughly mimic effects of natural, stand-replacement fires. More recently, foresters have recognized that burning irregularly shaped cutting units containing patches of uncut trees, while also creating snags, would far more effectively simulate effects of historical fires. An example of this approach on the Bitterroot National Forest is the Tolan Creek Timber Sale southeast of Darby, Montana, on the Sula Ranger District. Two large harvest blocks of 75 and 125 acres of lodgepole were treated with silviculture systems designed to simulate natural fire patterns. Seedtree reserves were retained in the pure lodgepole pine stands and shelterwoods with reserves were retained in the mixed Douglas-fir (*Pseudotsuga menziesii*)/lodgepole pine stands. Several lessons were learned there, including problems encountered with long skidding distances in such large units and narrow burning windows that made it difficult to accomplish site preparation. An additional, fairly common, result of the constraints of very narrow prescribed burning windows occurs when burning is postponed to the point when fine fuels are gone due to compaction and decay and fuels may need to be augmented to provide sufficient fire intensity to create snags by killing some trees and also to open serotinous cones. In this case, some planting may be required.

Recognition of the extent of the mixed-severity fire regime in lodgepole pine, and the recent success and experience gained from the Tolan Creek Timber Sale, have led to continued efforts toward more ecologically based management of lodgepole pine. In this paper we present new research and demonstration activities that may provide knowledge and techniques to manage lodgepole pine forests in the interior West. First, at the stand and watershed levels, we describe a current application of a suite of restoration treatments to lodgepole pine stands within a watershed in central Montana. Second, we move to a coarser spatial resolution and discuss a BEMRP study, which characterized landscape and patch dynamics in lodgepole pine forests and the implications for ecosystem management.

Restoration in Lodgepole Pine: A Mixed- and High-Severity Fire Regime

A major, watershed-scale research and demonstration study of ecosystem-based treatments in a subalpine lodgepole pine forest is being implemented on the 9,125-acre Tenderfoot Creek Experimental Forest (TCEF) in central

Montana (fig. 1). This study will test the feasibility of an array of management treatments that consider societal needs for wood products while maintaining lodgepole pine forests. The treatments are designed to emulate natural disturbance processes (predominately fire) while avoiding catastrophic-scale disturbances. While not directly funded by, or related to, the Bitterroot Ecosystem Management Research Project (BEMRP), the research and demonstration study at TCEF was deliberately initiated to meet the need for new management techniques for lodgepole pine on the Bitterroot National Forest as well as other areas in the interior Rocky Mountains. A number of attributes of the TCEF were attractive for this study: TCEF is an official Forest Service Experimental Forest, it is not near any significant or sensitive urban areas, it has not experienced any previous management activities (with the significant exception of fire suppression), and it is biophysically similar to common lodgepole pine stands found on the Bitterroot National Forest. Additional ecological attributes of TCEF enhancing its utility for this study included no evidence of mountain pine beetle, very little dwarf mistletoe, and scarce evidence of significant wind events.

Paired watersheds at TCEF have been monitored for several years and will serve as a basis for comparison of water quantity and quality under different cutting and burning treatments. A detailed fire history study and map has been completed that documents a sequence of stand replacement and mixed-severity fires extending back to 1580 (Barrett 1993). Stand-replacing burns occurred at intervals of 100 to over 300 years, with low- or mixed-severity burns often occurring within these intervals. Two-aged stands cover about half the area at TCEF, ranging in size from a few acres to about 1,000 acres.

Experimental treatments at TCEF have been designed to reflect these historical disturbance patterns. The study design for TCEF will integrate observations of on-site treatment response with water yield and water quality data from paired, experimental sub-watersheds that have monitoring flumes. The treatments include silviculture, prescribed fire, and silviculture-with-prescribed fire. The silvicultural system proposed is a two-aged system termed "shelterwood-with-reserves," with two forms of leave tree retention: one with leave trees evenly distributed, and the other with leave trees in a noticeably uneven pattern, suggestive of historical mixed-severity burns. A three-dimensional visualization depicting the two forms of retention is shown in figure 2. About 50 percent of the basal area will be removed. Low intensity underburns will follow in 50 percent of the harvested units. In addition, several large blocks (35 to100 acres) will be treated by mixed-severity underburning with no silvicultural treatments. The suite of treatments will be applied on each of the two, paired sub-watersheds—one with a southern aspect and one with a northern aspect (fig. 3). Immediately adjacent to each treatment sub-watershed is a hydrologically similar sub-watershed used as a no-treatment control.

Snag retention and/or recruitment objectives will be 9 to 15 trees per acre of 9 to 10 inches minimum diameter in three age classes. Changes in amounts of coarse woody debris will be assessed with respect to potential impacts on small mammal densities (Hardy and Reinhardt 1998).

Planning for this extensive study was initiated in 1995, and several Forest Service Research personnel were included as ex officio members of the interdisciplinary planning team assembled by the Lewis and Clark National Forest to accomplish the Environmental Assessment (EA) process required for the project. The EA was completed in 1998 and a final decision notice was issued in early 1999. Construction of approximately 2½ miles of roads will be accomplished in 1999 and harvesting should be completed by fall of 2000. Prescribed burning operations may be executed in 2001, if this aggressive schedule is executed without complications.

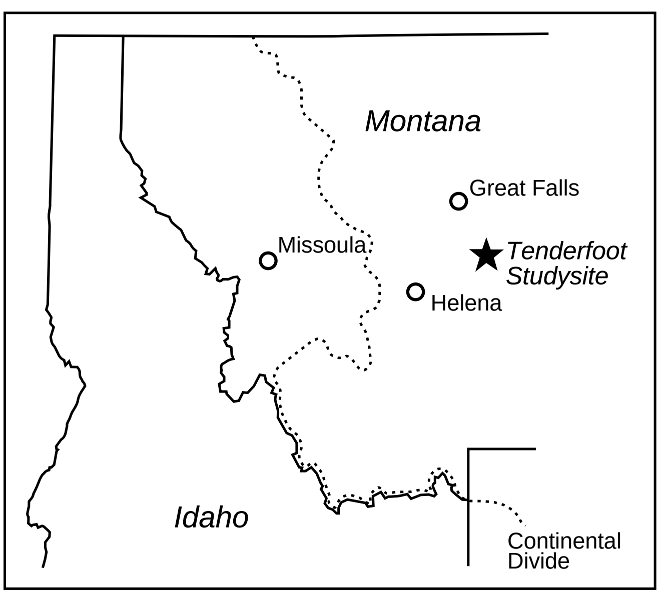


Figure 1—The Tenderfoot Creek study site is a USDA Forest Service Experimental Forest located in the Little Belt Mountain Range in central Montana.

Landscape and Patch Dynamics in Lodgepole Pine Forests: Implications for Ecosystem Management

General characteristics of disturbance regimes can often be described from landscape patch characteristics and dynamics (Hessburg and others, in press a; Forman 1995; Swanson and others 1990). We computed landscape metrics for ten Bitterroot National Forest lodgepole pine landscapes in order to (1) describe general landscape characteristics, (2) quantify a range of variation in these metrics for baseline threshold values, and, most importantly, (3) derive spatial treatment guidelines for harvesting and restoring these ecosystems.

Seven small landscapes on the Bitterroot National Forest (Bitterroot Forest), about 1,483 acres in size and composed primarily of lodgepole pine, were mapped from 1993 aerial photos using the methodology described by Hessburg and others (1998a). Additionally, three larger landscapes (9,884 to 37,065 acres) from the Interior Columbia Basin Ecosystem Management Project (ICBEMP) were mapped at two

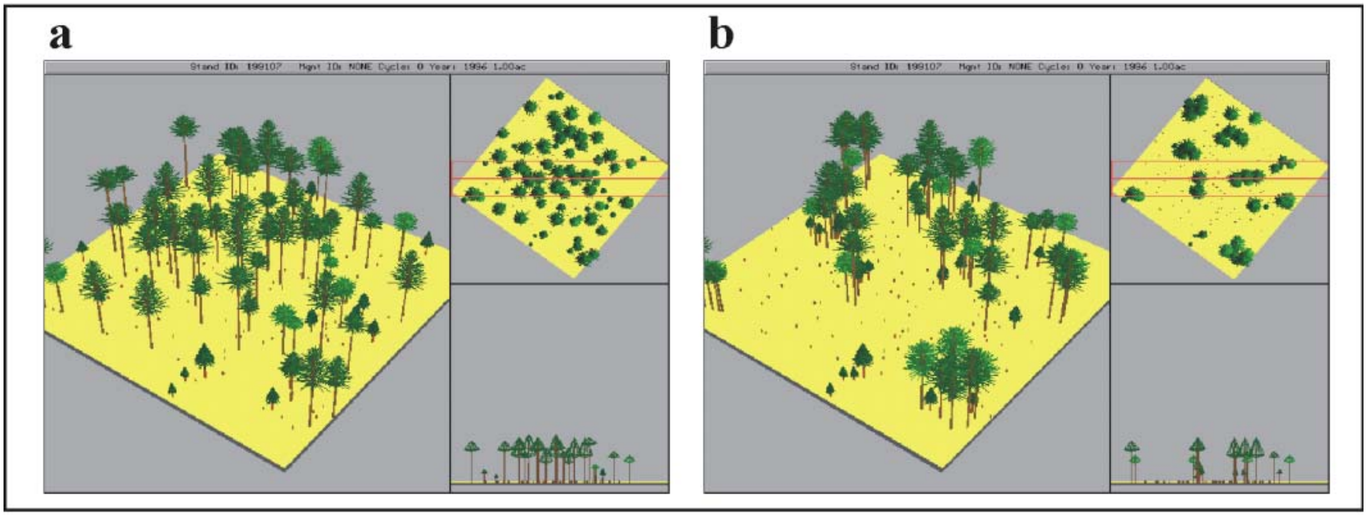


Figure 2—Visualizations depicting two distributions of retention trees: even distribution (a) and clumped distribution (b). Each of the treatments retains the same basal area, stem density, size distribution, and species composition.

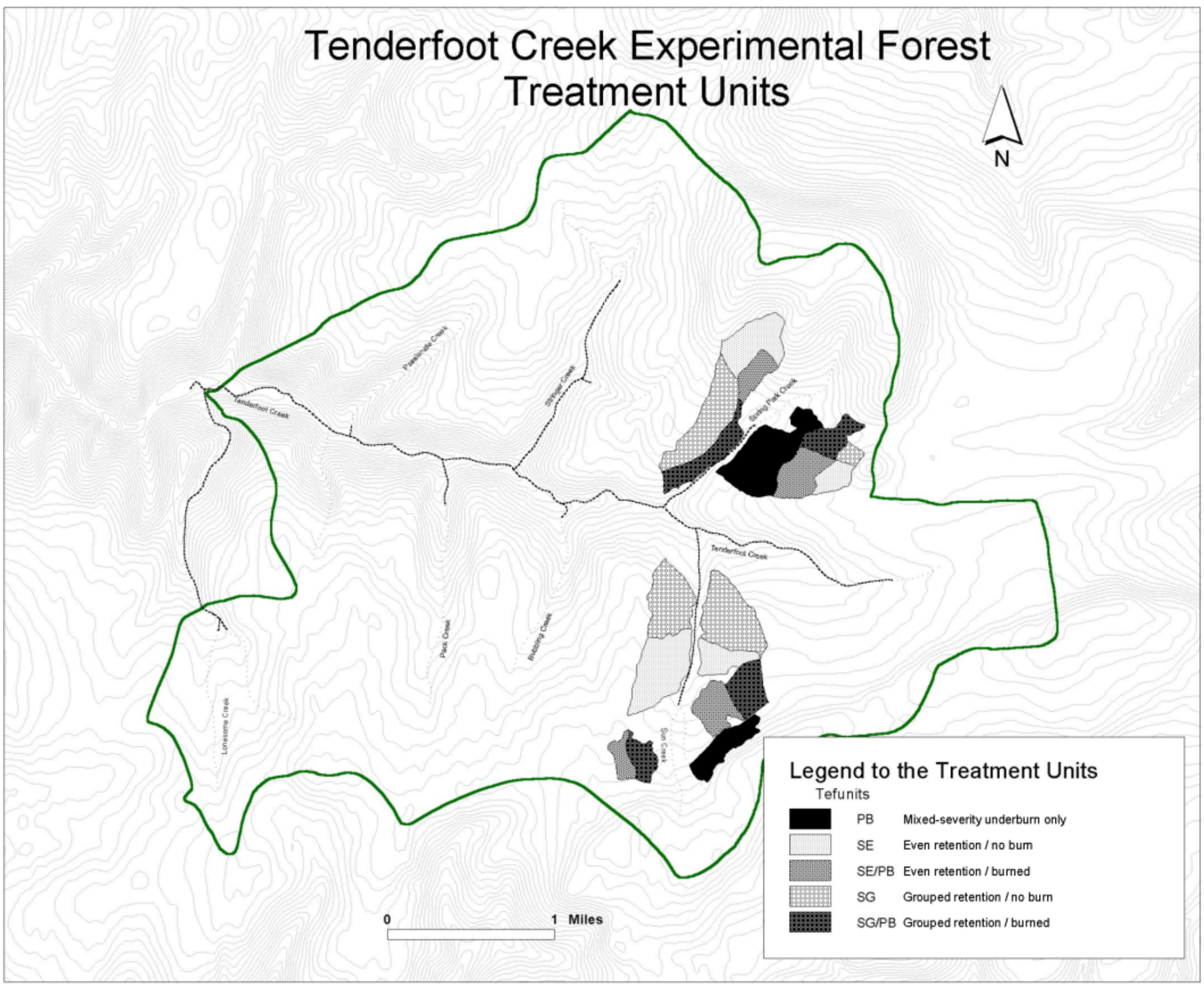


Figure 3—The 18 treatment units are distributed across Sun Creek (north aspect) and Spring Park Creek (south aspect) subwatersheds.

time intervals, 1937 and 1993. General descriptors for each of the ten sites are given in table 1. We then selected the attributes of cover type, structural stage, and canopy cover as the key polygon descriptors for this study. Spatial data layers were created for each landscape and then imported into the FRAGSTATS (McGarigal and others 1995) spatial pattern analysis program to compute the landscape metrics.

A comparison of ICBEMP historical to current landscape metrics reveals some interesting relationships. It appears historical landscapes had less subalpine fir and more pine and nonforest cover types than current landscapes (table 1). These pre-1940's landscapes had more early seral patches in the nonforested and seedling/sapling structural stages. Patches tended to be larger, more irregular, less contagious, and more diverse prior to the 1940's historical landmark (table 2). This is consistent with metrics computed for other current landscapes that have had fire exclusion for long time periods (Keane and others 1999; Hessburg and others, in press b). All current landscapes were heavily weighted toward the later structural stages with over 80 percent of the landscapes being older than seedling/saplings. Estimates of similar landscape metrics by Hessburg and others (1998b) were extremely close to those computed for the Bitterroot National Forest landscapes. They used 132, 6th HUC code watersheds in the east slope of the Cascades—a region quite distant from the Bitterroot valley. This may indicate that fire processes are similar across all landscapes that support lodgepole pine, a concept supported in the fire sciences literature (Heinselman 1981; Peet 1988; Wright 1974).

The most useful patch type or mapping entity to assess depends on management objectives. If management at the species level is required (e.g., return lodgepole to the landscape), then the cover type metrics should be used. We selected the combination of cover type and structural stage because this probably best represents the mosaic produced by fire regimes. The strata for which landscape metrics are shown in table 2 represents the combination of cover type and structural stage.

Table 1—General description of the 10 current and additional 3 historic landscapes employed in the landscape metric evaluation.

Landscape study area	Landscape assessment project	Study area size (ha)	Dominant cover type[a]	Dominant structural stage[a]	Dominant canopy cover[a]
Beaverwoods	BNF	766	Lodgepole pine	Pole	Moderate
Cow Creek	BNF	334	Douglas-fir	Pole	Moderate
Gibbons	BNF	593	Douglas-fir	Small	Moderate
Lick Creek	BNF	667	Douglas-fir	Pole	Low
St. Joe	BNF	476	Subalpine fir	Pole	Low
Sawmill	BNF	276	Subalpine fir	Small	Moderate
Sweeney	BNF	248	Douglas-fir	Small	Moderate
Sweeney-Joe					
Historical	ICRB	4,300	Subalpine fir	Nonforest	Low
Current	ICRB	4,300	Subalpine fir	Small	Low
Roaring Lion					
Historical	ICRB	6,573	Subalpine fir	Nonforest	Low
Current	ICRB	6,573	Subalpine fir	Nonforest	Moderate
Sleeping Child					
Historical	ICRB	14,398	Lodgepole pine	Small	Moderate
Current	ICRB	14,398	Subalpine fir	Small	Moderate

[a]Cover type, structural stage, and canopy cover are based on the most dominant category.

Table 2—Landscape metric evaluation statistics for all ten lodgepole pine landscapes show current and historic conditions (current/historic) for the combination of cover type and structural stage. The Sawmill landscape is presented as an example target landscape.

Landscape Metric[a]	"Target" landscape (Sawmill)	Metric statistics for all 10			
		Average	Minimum value	Maximum value	Standard error
		current/historic			
LPI (%)	20.3	12.7/14.4	5.6/7.1	24.6/27.2	1.8/6.4
MPS ha)	7.1	21.4/68.5	5.7/34.4	66.6/118.0	6.5/25.3
PSCV (%)	142.5	148.7/209.6	110.1/144.2	236.8/340.1	11.4/65.3

[a]LPI = landscape patch index; MPS = mean patch size; PSCV = patch size coefficient of variation.

Landscape characteristics important to **treatment design** are the size and variability of patches. Therefore, we recommend **mean patch size** (acres), **patch size coefficient of variation** (percent), and **landscape patch index** be used to design treatment units (table 2). **Mean patch size** (MPS) statistics provide a *target* patch size. In our study, the MPS for current landscapes (15 to 163 acres) was much lower than MPS computed for historical landscapes (84 to 291 acres). The **patch size coefficient of variation** (PSCV) can guide the manager as to the sideboards or boundaries in selecting a patch size. Data computed for historical and current landscapes show the PSCV was often much larger than the MPS indicating the wide variation of fire mosaics common on the Bitterroot landscape (table 2). Lastly, **landscape patch index** (LPI)—the maximum percent of the landscape occupied by one patch—provides an indication of the largest patch management activity should create on that landscape. Landscape metrics from an example target watershed (Sawmill) were compared to averages from the Bitterroot study and were found to be within the range of variation of both current and historical landscapes (table 2). On that basis, the largest patch to create on the Bitterroot landscapes would probably be between 20 to 40 percent of the total landscape (table 2).

Conclusions

With the exception of a comprehensive fire history study, the treatments currently being implemented on the Tenderfoot Creek Experimental Forest (TCEF) are an example of management activities designed without the benefit of landscape metrics analyses. In lieu of such metrics, the treatment design at TCEF reflects qualitative assessments of desired "patchiness" and also the desire to emulate the historical patterns of natural disturbance.

In contrast, spatial metrics provide a method of assessing the landscape structure and composition of individual watersheds prior to treatment to determine harvest or burn parameters, although the high variability between and across landscapes makes a "one-size-fits-all" set of recommendations nearly impossible. These data have shown that a target landscape, such as the Sawmill watershed used in this example, can be identified and that landscape metrics such as those shown here (MPS, PSCV, LPI) can be used to prescribe a desired condition for which management activities may be designed and implemented. However, data from this analysis are not suitable for computing frequency of treatment activity or fire rotation and are therefore somewhat limited in their use for design of treatment prescriptions in the absence of other information. Treatment scheduling in time and space is a complex and demanding task that must account for wildfire events, global climate change, management activities in parts of the landscape and in other ecosystems, and the current socio-political climate.

References

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Washington DC: Island Press. 493 p.

Arno, S.F. 1980. Forest fire history in the northern Rockies. Journal of Forestry. 78(8): 460-465.

Arno, Stephen F.; Reinhardt, E.D.; Scott, J.H. 1993. Forest structure and landscape patterns in the subalpine lodgepole pine type: A procedure for quantifying past and present conditions. Gen. Tech. Rep. INT-294. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 17 p.

Baker, William L. 1992. Effect of settlement and fire suppression on landscape structure. Ecology. 73(5): 1879-1887.

Baker, William L. 1995. Long term response of disturbance landscapes to human intervention and global change. Landscape Ecology. 10(3): 143-159.

Barrett. S.W. 1993. Fire history of Tenderfoot Creek Experimental Forest, Lewis and Clark National Forest. Contract completion report on file at the Rocky Mountain Research Station, Forestry Sciences Lab, Bozeman, MT.

Barrett, S.W.; Arno, S.F.; Key, C.H. 1991. Fire regimes of western larch-lodgepole pine forests in Glacier National Park, Montana. Canadian Journal of Forest Research. 21: 1711-1720.

Forman, R.T.T. 1995. Landscape mosaics—the ecology of landscapes and regions. Cambridge University Press, Great Britain. 632 p.

Hardy, C.C.; Reinhardt, E.D. 1998. Modeling effects of prescribed fire on wildlife habitat: stand structure, snag recruitment and coarse woody debris. In: Fire and wildlife in the Pacific Northwest—research, policy and management: Proceedings of a conference; 1998, April 6-8; Spokane, WA. Portland, OR: Northwest Section of the Wildlife Society: 67-74.

Heinselman, Miron, L. 1981. Fire intensity and frequency as factors in the distribution and structure of northern ecosystems. In: Mooney, H.A.; Bonnicksen, T.M.; Christensen, N.L.; Lotan, J.E.; Reiners, W.A., tech. cords. Proceedings of the conference: Fire Regimes and Ecosystem Properties. 1978 December 11-15; Honolulu, Hawaii, USA. Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service: 7-58.

Hessburg, P.F.; Smith, B.G.; Kreiter, S.G.; [and others]. [In press a]. Historical and current forest and range landscapes in the Interior Columbia River Basin and portions of the Klamath and Great Basins. Part II: Linking vegetation patterns and landscape vulnerability to potential insect and pathogen disturbances. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Hessburg, P.F.; Smith, B.G.; Salter, R.B. [In press b]. A method for detecting ecologically significant change in forest spatial patterns. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Keane, R.E.; Morgan, P.; White, J.D. 1999. Temporal pattern of ecosystem processes on simulated landscapes of Glacier National Park, USA. Landscape Ecology. 14: 311-329.

Lotan, J.E.; Critchfield, W.B. 1990. Pinus contorta Dougl. ex. Loud.—lodgepole pine. In: Burns, R.M.; Honkola, B.H., tech. coords. Silvics of North America: Vol. 1, Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 302-315.

McGarigal, Kevin; Marks, Barbara J. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. Gen. Tech. Rep. PNW-GTR-351. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 122 p.

Peet, Robert K. 1988. Forests of the Rocky Mountains. In: Barbour, M.G.; Billings, W.D., eds. North American Terrestrial Vegetation. Cambridge University Press, New York: 63-96.

Swanson, F.J.; Franklin, J.F.; Sedell, J.R. 1990. Landscape patterns, disturbance, and management in the Pacific Northwest, USA. In: Zonneveld, I.S.; Forman, R.T.T., eds. Changing Landscapes. Springer-Verlag, New York, New York: 191-213.

Wright, H.E. 1974. Landscape development, forest fires and wilderness management. Science. 186(4163): 487-495.

Ecosystem-Based Management in the Whitebark Pine Zone

Robert E. Keane
Stephen F. Arno
Catherine A. Stewart

Abstract—Declining whitebark pine (*Pinus albicaulis*) forests have necessitated development of innovative methods to restore these ecologically valuable, high elevation ecosystems. We have began an extensive restoration study using prescribed fire and silvicultural cuttings to return native ecological processes to degenerating whitebark pine forests. Preliminary results indicate these restoration treatments are successfully restoring the fire processes at a small scale, but many challenges need to be met to achieve landscape scale whitebark pine ecosystem restoration. Prescribed fires are difficult to implement because highly variable mountain weather rarely allows favorable burning conditions and the remote settings of many whitebark pine stands may preclude economically feasible silvicultural harvesting. However, we believe any fire or silvicultural treatment that reduces competing tree species densities and allows whitebark pine regeneration can potentially aid in the conservation of whitebark pine ecosystems.

Whitebark pine (*Pinus albicaulis*) is a major seral tree species found in most upper subalpine areas of the northern Rocky Mountains and Cascades in the United States and Canada that is rapidly declining (Arno and Hoff 1990; McCaughey and Schmidt 1990; see Schmidt and McDonald 1990). This "keystone" species is critical for the maintenance of many unique ecosystem processes in high elevation landscapes. Whitebark pine produces large, nutritious seeds that are highly valued as food by many species of wildlife (Hutchins and Lanner 1982; Weaver and Forcella 1986). One bird, the Clark's Nutcracker (*Nucifraga columbiana*), has evolved a mutualistic relationship with the pine (Tomback 1998; Tomback and others 1990); it harvests the large seeds from cones on the tree and then stores them on the ground in caches that can contain as many as 15 seeds (McCaughey and Schmidt 1990; Tomback and others 1990). Cached seed unclaimed by the nutcracker (about 5 to 20 percent of those cached) can germinate and may grow into viable whitebark pine seedlings (Tomback 1989; Hutchins and Lanner 1982). The nutcracker especially likes to cache seeds in open areas, like those created by fire (Tomback and others 1990), and the pine is more likely to survive to maturity in these openings because there are few competing trees (Arno and Hoff 1990). Moreover, the nutcracker can disperse whitebark pine seeds much farther (up to 20 km) than wind typically disperses seeds of other associated tree species.

Whitebark pine benefits from wildland fire because it is more capable of surviving fire and regenerating after fire than its associated shade-tolerant species (Arno and Hoff 1990). Whitebark pine is able to survive low severity fires because it has thicker bark, a thinner and higher crown, and deeper roots. It readily recolonizes large, stand-replacement burns because Clark's Nutcrackers transport the seeds from distant unburned stands (McCaughey and others 1985; Tomback and others 1993). In fact, essentially all whitebark pine regeneration originates from unclaimed nutcracker caches (Tomback and others 1990). When fire is excluded from the high mountain landscape, whitebark pine is eventually replaced by shade-tolerant subalpine fir (*Abies lasiocarpa*), spruce (*Picea engelmannii*), or mountain hemlock (*Tsuga mertensiana*) (Alexander and others 1990; McCaughey and Schmidt 1990).

Sadly, these diverse and unique forests have been rapidly declining in about 50 percent of the species' range because of recent blister rust (*Cronartium ribicola*) and mountain pine beetle (*Dentroctonous ponderosae*) epidemics, and advancing succession resulting from fire exclusion (Arno 1986; Kendall and Arno 1990; Keane and Arno 1993; Keane and others 1994). The exotic disease, blister rust, was introduced to western North America circa 1910 and quickly spread across the entire range of whitebark pine by 1961 (Hoff and Hagle 1990). During the same period, the United States government initiated an aggressive fire suppression program that has accelerated in magnitude and technology into the present. An extensive mountain pine beetle epidemic occurred during the early 1930's in west-central Montana and central Idaho that killed many mature whitebark pine, and additional beetle epidemics in recent decades have killed many of the remaining trees. The net result of these three factors is the rapid die-off of whitebark pine that has accelerated the successional replacement of whitebark pine with fir and spruce (Hartwell 1997; Keane and Arno 1993; Kendall and Arno 1990). The beetles and blister rust killed the large, cone-producing whitebark pine, thereby reducing whitebark pine seeding potential, and then fire exclusion reduced the number of sites suitable for nutcracker caching, allowing the invasion of fir and spruce.

The long-term, detrimental effects of blister rust, beetle, and fire exclusion policies on whitebark pine ecosystems have necessitated development of innovative techniques for restoring the health and function of these high elevation, keystone ecosystems across the landscape. This paper

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Robert E. Keane is a Research Ecologist and Stephen F. Arno is a retired Research Forester, Fire Effects Research Work Unit, USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, P.O. Box 8089, Missoula, MT 59837, phone: (406) 329-4846, FAX: (406-329-4877. Catherine A. Stewart is the Fire Ecologist, Lolo National Forest, Northern Region, USDA Forest Service, Missoula, MT.

summarizes the lessons learned from an ongoing, seven year study investigating methods for restoring whitebark pine to the high elevation landscape in and around the Bitterroot Mountains of west-central Montana and east-central Idaho (Keane and Arno 1996; Keane and others 1996a). This project, called *Restoring Whitebark Pine Ecosystems* (RWPE), involves five research sites (fig. 1) in whitebark pine forests that are different in biophysical environment, stages of decline, and stand structure. Prescribed burning and silvicultural harvest systems are being employed to reestablish and maintain whitebark pine in these areas.

Lessons Learned

Restoration Is Needed

Extensive field sampling and simulation modeling show that, without proactive restoration treatments, whitebark pine forests will continue to decline, forever changing the character of high mountain landscapes (Kendall and Arno 1990; Arno 1986; Keane and others 1990; Keane and others 1996b; Keane and others 1994). Today's continued fire exclusion policies, coupled with extensive and expanding rust epidemics, will continue to reduce whitebark pine to critically low levels.

There is concern by many ecologists that whitebark pine populations may become so low that the nutcracker will eat most seeds and cache very few, thereby becoming a seed predator rather than a seed disperser. Another concern is that nutcrackers may start frequenting other low elevation forests to the exclusion of whitebark pine forests with dwindling seed crops. And without fire creating openings and killing the fir and spruce, the limited number of nutcracker-cached seed in high elevation landscapes will rarely become cone-producing trees because of the excessive competition. Furthermore, natural blister rust resistance in the pine will never be passed along to progeny because there will be no openings to allow seedling growth.

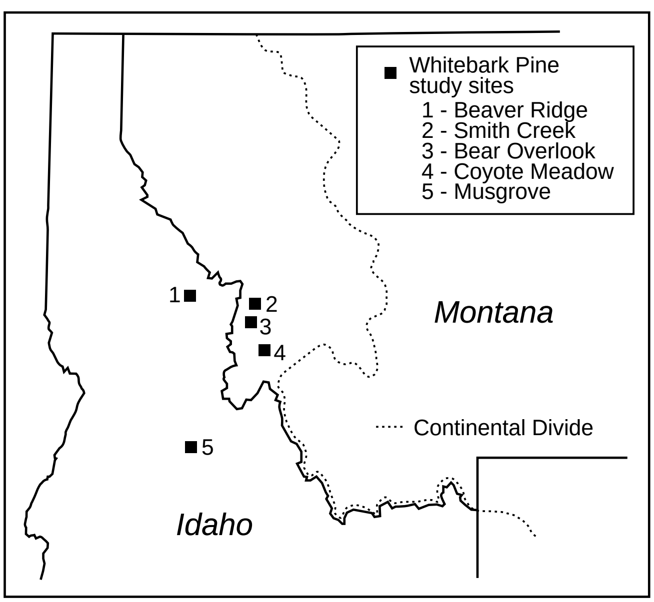


Figure 1—Whitebark pine research restoration sites in west-central Montana and Idaho.

The Most Effective Restoration Treatments

Prescribed burning and selection cuttings, either alone or together, are the most practical restoration treatments we have found so far. Prescribed burning is useful because it returns fire to the ecosystem. Selection cuttings (i.e., removing shade-tolerant fir and spruce) are effective in areas where burning is difficult (e.g., heavy fuel loads, adjacent to sensitive areas) and access is available (Debell and others 1997). These cuttings ensure selective removal of certain trees (e.g., firs) and generate cured slash that can aid implementation of prescribed fire in an environment that is otherwise difficult to burn except under severe fire weather. However, prescribed burning is usually necessary after a cutting because fire kills the numerous small fir and spruce seedlings that escaped the cutting. Fire also reduces slash to clear the ground for optimal nutcracker caching (Keane and Arno 1996; Lasko 1990; Tomback and others 1993).

Based on historical stand structures, we feel any crown, mixed severity, or surface fire could be justified in a mixed severity regime, so design characteristics of mixed severity fires can be very liberal, depending on the restoration objective and the current site conditions (Arno and others 1993; Morgan and others 1994; Norment 1991). Development of "one-size-fits-all" treatments and fire prescriptions are especially futile in whitebark pine forests because of the high degree of variability in pattern, process, composition, and structure.

Successful restoration treatments were implemented on the five RWPE study sites (fig. 1). Circular, 0.5 to 2 acre harvest units, called nutcracker openings, were created at the Smith Creek and Beaver Ridge sites by removing all trees but cone-bearing whitebark pine to encourage nutcracker caching. Prescribed burning inside nutcracker openings and within unharvested units at Smith Creek killed over 40 percent mature subalpine fir and reduced fuel loadings by 45 percent to create ideal caching habitat for the nutcracker. Cutting at the Bear Overlook, Coyote Meadows, and Musgrove sites was done to (1) eliminate fir and spruce competition, (2) create slash fuels to enhance fire spread, and (3) widen prescribed burning windows. One limitation of the RWPE study is all treatments were planned and implemented at the stand level, and successful, long-term restoration of whitebark pine needs to be accomplished at the landscape level.

It takes great patience to restore whitebark pine ecosystems with prescribed burning. High elevation whitebark pine forests are rarely sufficiently dry in the summer to conduct a prescribed burn because of late snowmelt and abundant summer precipitation. Then, in those occasional years where the high country is dry enough for a summer fire, the rest of the landscape is usually in extreme fire danger, and spotting from high elevation fires may start severe fires in low elevation forests (Brown and others 1994). Sometimes one or more years will pass before the right set of conditions allows the implementation of a prescribed burn.

We have been waiting six years to burn the high elevation Coyote Meadows study area.

Autumn seems to be the best season to initiate prescribed fire in whitebark pine forests providing fire danger is low in adjacent, low elevation areas. Since fine herbaceous and woody fuels are rarely cured by the beginning of fall because of high summer precipitation, it is essential that an early, hard frost kill most herbaceous plants and shrub foliage so they will dry quickly and provide dry fine fuels for fire propagation. Usually, the ensuing warm "Indian summer" conditions, common for many western autumns, dry frost-killed plant parts enough to carry a fire.

Probably the most practical tool for creating many, large openings over extensive, remote landscapes are prescribed natural fires, more recently termed wildland fire for resource benefit (WFRB) (Keane and Arno 1996). A WFRB is a lightning ignition that is allowed to burn within a given set of weather and fuel conditions (i.e., prescription), often without being confined by fire line or other man-made fuel breaks. Many whitebark pine forests are found in roadless or wilderness settings with little or no road access, so fire control structures used in conventional prescribed fire, such as hand-line and dozer lines, are costly and infeasible.

WFRB have many advantages. First, ignitions usually occur during the summer, the season when most whitebark pine forests burned historically. Second, a summer ignition can be allowed to burn over many weeks, creating a mosaic of low to high severity fire patterns across the burned area, which was historically common in whitebark pine forests. This makes WFRBs useful landscape restoration tools for both mixed severity and stand-replacement fire regimes. Third, more area can be treated more cheaply with WFRBs than with conventional prescribed fire because fire control structures are minimal and usually fewer people manage the fire. Fire managers risk a great deal with WFRBs because the fires can become uncontrollable wildfires due to the lack of control structures and long burning seasons, endangering human life and property.

Even an extensive burning program cannot rely solely on lightning ignitions. Brown and others (1994) found the highly successful WFRB program in the Selway-Bitterroot Wilderness Area did not burn sufficient area in the whitebark pine type (only 38 percent of historical fires). This is primarily because when whitebark pine forests finally become dry enough to burn, the lower elevation forests were usually very dry and in extreme fire danger. As a result, fire managers are unable or unwilling to allow any new ignitions to burn on the landscape, especially those ignitions in whitebark pine. Therefore, management-ignited prescribed fires, a fire started by fire managers and allowed to burn without fire control within a fire prescription, will probably be needed in the future to restore whitebark pine landscapes.

A Restoration Strategy

Whitebark pine ecosystem restoration does not exclusively imply that historical stand structures be recreated using silviculture or prescribed fire (Apfelbaum and Chapman 1997; Bonnicksen and Stone 1985). To succeed over the long term, ecosystem restoration must emphasize the return of ecosystem processes rather than historical stand and landscape structures and compositions (Crow and Gustafson 1997; Michener 1997; Parsons and others 1986). Historical disturbance regimes, stand structures, and landscape patterns should be used as guides rather than goals in restoration efforts. It is more important that restored processes be in agreement with current and future abiotic and biotic conditions so that restoration activities will have long-term success (Apfelbaum and Chapman 1997). Once important processes, such as the fire regime, are restored to an ecosystem, suitable stand and landscape structures and compositions will follow (Bell and others 1997; Parsons and others 1986). This becomes somewhat problematic when an exotic disease like blister rust devastates whitebark pine stands, but it is still the most viable alternative.

Maintenance of native fire regimes is the single most important management action to ensure conservation of whitebark pine into the future because it creates favorable habitat for seed caching by Clark's nutcrackers that will effectively regenerate whitebark pine and enhance natural rust resistance (Keane and others 1990). It is important to design restoration treatments to match the characteristics of natural disturbance processes prevalent on the project landscape, and since fire shaped most historical whitebark pine landscapes, it would be desirable to craft restorative treatments to emulate fire's effect.

Flexibility is crucial for restoration projects in whitebark pine because fire and climate regimes are notoriously variable in time and space. Scheduling treatments and designing future landscapes may be a futile task. The future pattern, severity, and frequency of wildland fires are especially difficult to quantify or describe for a particular spatial or temporal scale. Climate and weather have and will continue to change, and the rate of structural and compositional development across a landscape is also highly variable (Baker 1990; Bartlein and others 1997; Ferguson 1997). It is also highly probable that political, social, and biological climates will change during the century-long successional periods common in whitebark pine forests, and major advances in research and technology can quickly render planned restoration treatments ineffective or obsolete. So instead of conventional treatment schedules, managers may want to take an adaptive management approach to managing landscapes where all landscapes would be evaluated every 10 to 20 years to assess their need for restoration and plan accordingly. Each assessment can integrate the current state of scientific knowledge and technology and then adjust for any changes in the sociopolitical and biophysical environment.

Monitoring effects of restoration treatments is important because it provides feedback as to the success of the treatments for the specified objective to the entire land management community (Michener 1997). More importantly, monitoring is critical for building comprehensive knowledge bases for others to use in their restoration projects. This is especially important in these little studied, rust ravaged ecosystems because there are so few examples of successful treatments. Most monitoring can be accomplished by remeasurement of permanent plots, and taking repeat photographs from fixed points is a valuable, low-cost tool to compliment these measurements. Monitoring design can be intensive, where many variables are measured on numerous plots (Keane and Arno 1996), or less rigorous, where a limited set of measurements are taken on only a few representative plots (Michener 1997).

Restoration Is Feasible

Early results from RWPE restoration treatments, and again from simulation modeling, show prescribed burning and selective cutting treatments can be highly effective for restoring whitebark pine (Keane and Arno 1996; Keane and others 1996a; Keane and others 1990; Keane and others 1994). Moreover, our observations in this ecosystem lead us to believe that any ecologically sound treatment that opens the canopy and reduces subalpine fir competition will be successful. Granted, rust may kill some pine regeneration established after treatment, but chances are there will be a high level of rust resistance in the surviving seedlings. This resistance can then be passed to their progeny, ultimately conserving the species through natural breeding programs. The only way this can work at scales large enough to ensure the whitebark pine conservation is with an active fire program that utilizes conventional prescribed burning, WFRB, and manager-ignited fires to restore fire excluded ecosystems and maintain fire regimes.

Acknowledgments

We would like to thank Helen Smith, Janet Howard, Jane Kapler Smith, and Scott Mincemoyer, USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT, for their comments and review of the manuscript.

References

Alexander, R.R.; Shearer, R.C.; Shepperd, W.C. 1990. *Abies lasiocarpa* Subalpine fir. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North America: Vol. 1, Conifers. Agric. Handb. 654. Washington, D.C.: U.S. Department of Agriculture, Forest Service: 60-70.

Apfelbaum, S.I.; Chapman, K.A. 1997. Ecological restoration: a practical approach. Ecosystem management: applications for sustainable forest and wildlife resources. New Haven, CT: Yale University Press: 301-322.

Arno, Stephen F. 1986. Whitebark pine cone crops—a diminishing source of wildlife food? Western Journal of Applied Forestry. 1: 92-94.

Arno, Stephen F.; Hoff, Raymond. 1990. *Pinus albicaulis* Engelm. Whitebark Pine. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North America: Vol. 1, Conifers. Agric. Handb. 654. Washington, D.C.: U.S. Department of Agriculture, Forest Service: 268-279.

Arno, Stephen F.; Reinhardt, Elizabeth; Scott, J. 1993. Forest structure and landscape patterns in the subalpine lodgepole pine type: A procedure for quantifying past and present conditions. Gen. Tech. Rep. INT-294. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 50 p.

Baker, R.G. 1990. Late Quaternary history of whitebark pine in the Rocky Mountains. In: Schmidt, W.C.; McDonald, K.J., comps. Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high mountain resource. 1989 March 29-31; Bozeman, MT. Gen. Tech. Rep. INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 40-49.

Bartlein, P.J.; Whitlock, C.; Shafer, S.L. 1997. Future climate in the Yellowstone National Park and its potential impact on vegetation. Conservation Biology. 11(3): 782-792.

Bell, S.S.; Fonseca, M.S.; Motten, L.B. 1997. Linking restoration and landscape ecology. Restoration Ecology. 5(4): 318-323.

Bonnicksen, T.M.; Stone, E.C. 1985. Restoring naturalness to national parks. Environmental Management. 9: 479-486.

Brown, J.K., Arno, S.F.; Barrett, S.W.; Menakis, J.P. 1994. Comparing the prescribed natural fire program with presettlement fires in the Selway-Bitterroot Wilderness. International Journal of Wildland Fire. 4(3): 157-168.

Crow, T.R.; Gustafson, E.J. 1997. Ecosystem management: Managing natural resources in time and space. In: Kohm, K.A.; Franklin, J.F., eds. Creating Forestry for the 21st Century. Washington, D.C.: Island Press: 215-229.

DeBell, D.S.; Curtis, R.O.; Harrington, C.A.; Tappeiner, J.C. 1997. Shaping stand development through silvicultural practices. In: Kohm, K.A.; Franklin, J.F., eds. Creating Forestry for the 21st Century. Washington, D.C.: Island Press: 141-148.

Ferguson, Sue A. 1997. A climate-change scenario for the Interior Columbia River Basin. Gen. Tech. Rep. PNW-GTR-499. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 9 p.

Hartwell, M. 1997. Comparing historic and present conifer species compositions and structures on forested landscapes of the Bitterroot Front. Contract completion report for RJVA-94928 on file at the Fire Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807.

Hoff, R.; Hagle, S. 1990. Diseases of whitebark pine with special emphasis on white pine blister rust. In: Schmidt W.C.; McDonald, K.J., comps. Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high mountain resource. 1989 March 29-31; Bozeman, MT. Gen. Tech. Rep. INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 179-190.

Hutchins, H.E.; Lanner, R.M. 1982. The central role of Clark's nutcrackers in the dispersal and establishment of whitebark pine. Oecologia. 55: 192-201.

Keane, R.E.; Arno, S.F. 1993. Rapid decline of whitebark pine in western Montana: Evidence from 20-year remeasurements. Western Journal of Applied Forestry. 8(2): 44-47.

Keane, R.E.; Arno, S.F. 1996. Whitebark Pine (*Pinus albicaulis*) ecosystem restoration in western Montana. In: Arno, S.F.; Hardy, C.C., eds. The use of fire in forest restoration, a general session at the annual meeting of the Society of Ecosystem Restoration. 1995 September 14-16; Seattle, WA. Gen. Tech. Rep. INT-GTR-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 51-54.

Keane, R.E.; Arno, S.F.; Brown, J.K.; Tomback, D.F. 1990. Modeling disturbances and conifer succession in whitebark pine forests. In: Schmidt, W.C.; McDonald, K.J., comps. Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high mountain resource. 1989 March 29-31; Bozeman, MT. Gen. Tech. Rep. INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 274-288.

Keane, R.E.; Arno, S.F.; Stewart, C. 1996a. Restoration of upper subalpine whitebark pine ecosystems in western Montana. In: Mathiasen, R.L. ed. Proceedings of the 43 annual Western International Forest Disease Work Conference, 1995 August 29-September 1; Whitefish, MT. Coeur d'Alene, ID: Idaho Department of State Lands: 105-111.

Keane, R.E.; Menakis, J.P.; Hann, W.J. 1996b. Coarse scale restoration planning and design in Interior Columbia River Basin Ecosystems—An example using Whitebark Pine *(Pinus albicaulis)* forests. In: Arno, S.F.; Hardy, C.C., eds. The use of fire in forest restoration, a general session at the annual meeting of the Society of Ecosystem Restoration. 1995 September 14-16; Seattle, WA. Gen. Tech. Rep. INT-GTR-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 14-20.

Keane, R.E.; Morgan, P.; Menakis, J.P. 1994. Landscape assessment of the decline of whitebark pine (*Pinus albicaulis*) in the Bob Marshall Wilderness Complex, Montana, USA. Northwest Science. 68(3): 213-229.

Kendall, K.C.; Arno, S.F. 1990. Whitebark pine—an important but endangered wildlife resource. In: Schmidt, W.C.; McDonald, K.J., comps. Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high mountain resource. 1989 March 29-31; Bozeman, MT. Gen. Tech. Rep. INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 264-274.

Lasko, R.J. 1990. Fire behavior characteristics and management implications in whitebark pine ecosystems. In: Schmidt, W.C.; McDonald, K.J., comps. Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high mountain resource. 1989 March 29-31; Bozeman, MT. Gen. Tech. Rep. INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 319-324.

McCaughey, W.W.; Schmidt, W.C. 1990. Autecology of whitebark pine. In: Schmidt, W.C.; McDonald, K.J., comps. Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high mountain resource. 1989 March 29-31; Bozeman, MT. Gen. Tech. Rep. INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 85-95.

McCaughey, Ward W.; Schmidt, W.C; Shearer, R.C. 1985. Seed-dispersal characteristics of conifers of the Inland Mountain West. In: Shearer, R.C., com. Proceedings: Conifer Tree Seed in the Inland Mountain West Symposium. 1985 April 5-6 April 1985, Missoula, MT. Gen. Tech. Rep. INT-203. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 50-62.

Michener, W.K. 1997. Quantitatively evaluating restoration experiments: Research design, statistical analysis, and data management considerations. Restoration Ecology. 5(4): 324-337.

Morgan, P.; Bunting, S.C.; Keane, R.E.; Arno, S.F. 1994. Fire ecology of whitebark pine *(Pinus albicaulis)* forests in the Rocky Mountains, USA. In: Schmidt, W.C.; Holtmeier, F-K., comps. Proceedings—International workshop on subalpine stone pines and their environment: the status of our knowledge. 1992 September 5-11; St. Moritz, Switzerland. Gen. Tech. Rep. INT-GTR-309. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 136-142.

Norment, C.J. 1991. Bird use of forest patches in the subalpine forest-alpine tundra ecotone of the Beartooth Mountains, Wyoming. Northwest Science. 65(1): 1-10.

Parsons, D.J.; Graber, D.M.; Agee, J.K.; van Wagtendonk, J.W. 1986. Natural fire management in National Parks. Environmental Management. 10: 21-24.

Schmidt, Wyman; McDonald, Kathy, comps. 1990. Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high mountain resource. 1989 March 29-31; Bozeman, MT. Gen. Tech. Rep. INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 386 p.

Tomback, D.F. 1989. The broken circle: fire, birds and whitebark pine. In: Walsh, T., comp. Wilderness and Wildfire. [Date of conference unknown]; Missoula, MT. Misc. Pub. 50. Missoula, MT: University of Montana, School of Forestry, Wilderness Institute, Montana Forest and Range Experiment Station: 14-17.

Tomback, D.F. 1998. Clark's Nutcracker (*Nucifraga columbiana*). In: The Birds of North America, No. 331 (A. Poole and F. Gill, eds.). Philadelphia, PA: The Birds of North America, Inc. 24 p.

Tomback, D. F.; Hoffman, L.A.; Sund, S. K. 1990. Coevolution of whitebark pine and nutcrackers: Implications for forest regeneration. In: Schmidt, W.C.; McDonald, K.J., comps. Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high mountain resource. 1989 March 29-31; Bozeman, MT. Gen. Tech. Rep. INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 118-130.

Tomback, D.F.; Sund, S.K.; Hoffman, L.A. 1993. Post-fire regeneration of *Pinus albicaulis*: height-age relationships, age structure, and microsite characteristics. Canadian Journal of Forest Research. 23: 113-119.

Weaver, T.; Forcella, F. 1986. Cone production in *Pinus albicaulis* forests. In: Shearer, R.C., com. Proceedings: Conifer Tree Seed in the Inland Mountain West Symposium. 1985 April 5-6 April 1985, Missoula, MT. Gen. Tech. Rep. INT-203. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 68-76.

Presence/Absence as a Metric for Monitoring Vertebrate Populations

Len Ruggiero
Dean Pearson

Abstract—Developing cost effective methods for monitoring vertebrate populations is a persistent problem in wildlife biology. Population demographic data is too costly and time intensive to acquire, so researchers have begun investigating presence/absence sampling as a means for monitoring wildlife populations. We examined three important assumptions regarding the probability of detection (POD) requisite to implementing presence/absence sampling for wildlife monitoring: constant POD within species among sampling visits, among years, and among habitats. POD was constant for all small mammals examined between habitats and for most small mammals among visits and between years. Presence/absence may eventually serve as an effective means of monitoring some wildlife populations for demographic changes over time, but additional research will be necessary to further test these and other assumptions.

One of the greatest challenges facing wildlife managers is that of monitoring wildlife populations. Estimates of relative abundance and density are often successfully employed in comparing wildlife populations between habitats within the same time period. However, populations can exhibit dramatic natural year-to-year variation that renders population monitoring over time infeasible for most species of concern because of excessive cost and effort necessary to detect biologically significant changes in populations (Verner 1983). More recent work has been directed toward using data on a species presence or absence as a means of monitoring for trends in wildlife populations (Azuma and others 1990). However, presence/absence methods, though easier and cheaper to implement, still do not overcome the problem of excessive effort and cost (Zielinski and Stauffer 1996).

An alternative approach to using presence/absence data for monitoring population trends is the use of these data for monitoring changes in the distribution of a species over time. For example, if an area is gridded and grid cells are monitored for the presence or absence of a species, a reduction in the number of grid cells where the species is detected could effectively indicate a population decline. Monitoring for distributional changes of this sort is less demanding than monitoring population trends.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Len Ruggiero is the Project Leader and Dean Pearson is a Wildlife Biologist, Wildlife Habitat Relationships Unit, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 8089, Missoula, MT 59807 U.S.A., e-mail: lruggiero@fs.fed.us AND dpearson@fs.fed.us

Additionally, low cost, low effort presence/absence techniques allow for geographically extensive sampling. Extensive presence/absence information is particularly appealing from a conservation standpoint because such data provide not only information about changing distributions, but also allow biologists to determine the aerial extent and connectivity or isolation of wildlife populations on the landscape (e.g., Zielinski and others 1995). Although hundreds of distribution maps can be found in field guides for birds and mammals, more refined maps indicating where wildlife populations actually occur within the broad-brush species ranges are virtually non-existent.

However, in order for presence/absence sampling to be successful, the effort necessary to obtain reliable presence/absence estimates must be minimal such that extensive areas can effectively be sampled. In addition to this criterion, several critical assumptions must be met that are common to all population indices. The probability of detection (POD) must not vary in space or time (Thompson and others 1998), and the POD must be constant for repeated visits to correct for detection errors using the binomial distribution (Zielinski and Stauffer 1996). Thompson and others (1998) also suggested that POD must be linearly correlated with density.

In the current study we attempted to determine the following: (1) proportion of the small mammal communities in ponderosa pine (*Pinus ponderosa*) and western larch (*Larix occidentalis*) cover types that is effectively sampled for varying sampling effort in time, (2) species detection rates or probabilities of detection (POD) and how they differ between habitats and years for each species, and (3) consistency of the POD among visits within and among species.

Methods

The study area consisted of nine sites located throughout west-central Montana. Five sites were dominated by old-growth ponderosa pine, and four sites were dominated by mature western larch. Three transects and three grids of 25 Sherman live traps were placed within each of the nine sites by randomly selecting starting points and randomly orienting the grid or transect to a cardinal direction. Trap spacing was 10 m for transects and grids, resulting in 50-m by 50-m grids and 250-m transects. Squirrel-size Tomahawk wire-mesh live traps were placed at the four corners of each grid (40-m interval) and at 40-m intervals along transects, beginning with trap station one and extending for 120 m (four Tomahawk traps). Due to limited numbers of Tomahawk traps, only the first two grids and transects on each site included Tomahawks. All traps were baited with a mixture of peanut butter and whole oats and run for eight consecutive days. Tomahawk traps were also baited with strawberry jam to increase the likelihood of capturing northern flying squirrels (*Glaucomys sabrinus*). Traps were checked each morning and small mammals were ear tagged, identified to species, aged, weighed, sexed, their reproductive condition was determined, and they were released at the trap station. Stands were trapped in 1997 and 1998, beginning in May and ending in July.

We calculated latency to detection (LTD) to assess members of the communities that were likely to be detected by different sample periods. LTD was defined as the number of days until an individual was first detected at a sampling unit (each transect and grid is a sample unit). Probability of detection was defined as POD = D_{ij}/D_{i8}; where D is the number of sample units detecting species i by day j, and D_{i8} is the occurrence of species i by day 8. Because we defined a species occurrence as its detection on a site by day eight, POD may be biased for some organisms. The assumption of constant POD was tested for each species by visually assessing goodness of fit of the POD data for D_{i2}/D_{i8} against a model for constant POD based on the binomial distribution: $D(1-D)^{k-1}$; where k = the number of sampling visits. We tested for differences in POD_{i2} between habitats and years for the five most abundant species using hierarchical logistic regression with an index of abundance (the number of individuals captured by day 8 at a sample unit) entered in the first step and cover type and year entered simultaneously in the second step. The hierarchical approach was taken to control for abundance in order to assess the influence of habitat and year independent of the effect of abundance, since abundance is known to affect POD (Thompson and others 1998; Hayek and Buzas 1997).

Results

We captured 2,007 individuals of 16 species over the course of the study. We treat here only the 15 species detected at ≥3 sampling units. Most species (60 percent) appeared to exhibit a constant POD over time when compared to expectation (fig. 1). However, three species appeared to exhibit negative deviations from the constant POD model, and we could not assess three other species that had high initial POD because they rapidly achieved POD of one. Latency to detection estimates indicated that on average 46 percent of the species could be sampled in <3 days. Relative abundance produced significant logistic regression models for predicting POD_2 for deer mice (*Peromyscus maniculatus*) (c^2 = 19.67, df = 1, P < 0.001), yellow-pine chipmunks (*Tamias amoenus*) (c^2 = 5.94, df = 1, P = 0.015), and red-backed voles (*Clethrionomys gapperi*) (c^2 = 18.55, df = 1, P < 0.001), but not for golden-mantled ground squirrels (*Spermophilus lateralis*) and red-tailed chipmunks (*T. ruficaudus*). However, the logistic regression model predicting POD_2 for golden-mantled ground squirrels was nearly significant, so we ran the regression again for POD_3 and found the model for abundance was significant (c^2 = 6.34, df = 1, P = 0.012) for this sampling interval. Probability of detection did not differ by cover type after controlling for abundance for any of the five species examined, and year differed only for the red-tailed chipmunk (Wald = 6.95, df = 1, P = 0.008).

Discussion

For presence/absence sampling to be an effective tool to assess wildlife habitat relationships at landscape scales, or to monitor for changes in distributions of wildlife populations, these methods must be efficient, that is, they must quickly and effectively sample the target species with minimal effort. Additionally, detection success must be high or error corrections must be applied to adjust for false negatives (i.e., concluding a species is absent when it is present), and POD must not vary by habitat, year, or visit or more intensive sampling will be necessary to develop complex corrections.

We found that only 46 percent of the small mammals observed in western larch and ponderosa pine communities in west-central Montana were detected in less than three days. Furthermore, for sites where species were known to be present, most species (80 percent) exhibited low detection rates of <25 percent or <50 percent for the first and second visits respectively. Such high detection error would greatly diminish the efficacy of sampling of these species unless a correction for detection error could be applied. Methods for adjusting for detection errors based on understandings of the binomial distribution have been developed by Azuma and others (1990) and applied by Zielinski and Stauffer (1996), but these methods are based on the assumption of a constant POD for repeated visits to a site. If the POD for an organism is not constant over time, error adjustments based on the binomial distribution cannot be applied.

Although our sample sizes are not large enough to statistically test for constant POD for most species, a visual comparison of distributions suggests that most species (60 percent) appeared to exhibit a constant POD. The three species that exhibited high detection rates, deer mice, red-backed voles, and bushy-tailed woodrats (*Neotoma cinerea*), converged on a POD of one too rapidly to assess the assumption of constant POD. Three other species, the red squirrel (*Tamiasciurus hudsonicus*), the long-tailed vole (*Microtus longicaudus*), and the columbian ground squirrel (*S. columbianus*), went undetected for the first three to four days, then rapidly achieved high detection rates soon after. These data are quite interesting in that they establish the importance of deviations from the constant probability model. Although we could not assess the assumption of constant POD for the species with high detection rates, these species are not problematic in that, although they may not conform to error estimates based on the binomial distribution, error corrections are unnecessary because errors are insignificant. However, deviations from the constant POD model that result in high LTD times or very low POD followed by rapidly increasing POD are problematic. Such species defy early detection and so will rarely be sampled in spite of their presence. For such species, correcting for detection error is particularly important. However, error adjustments based on the binomial distribution can not be applied because the assumption of constant POD is not met. Intensive sampling would be necessary to develop species-dependent models to apply corrections to POD for these species.

In general, the constant POD model can be thought of as a null model for behavioral responses to detection methods because deviations from this model indicate behavioral

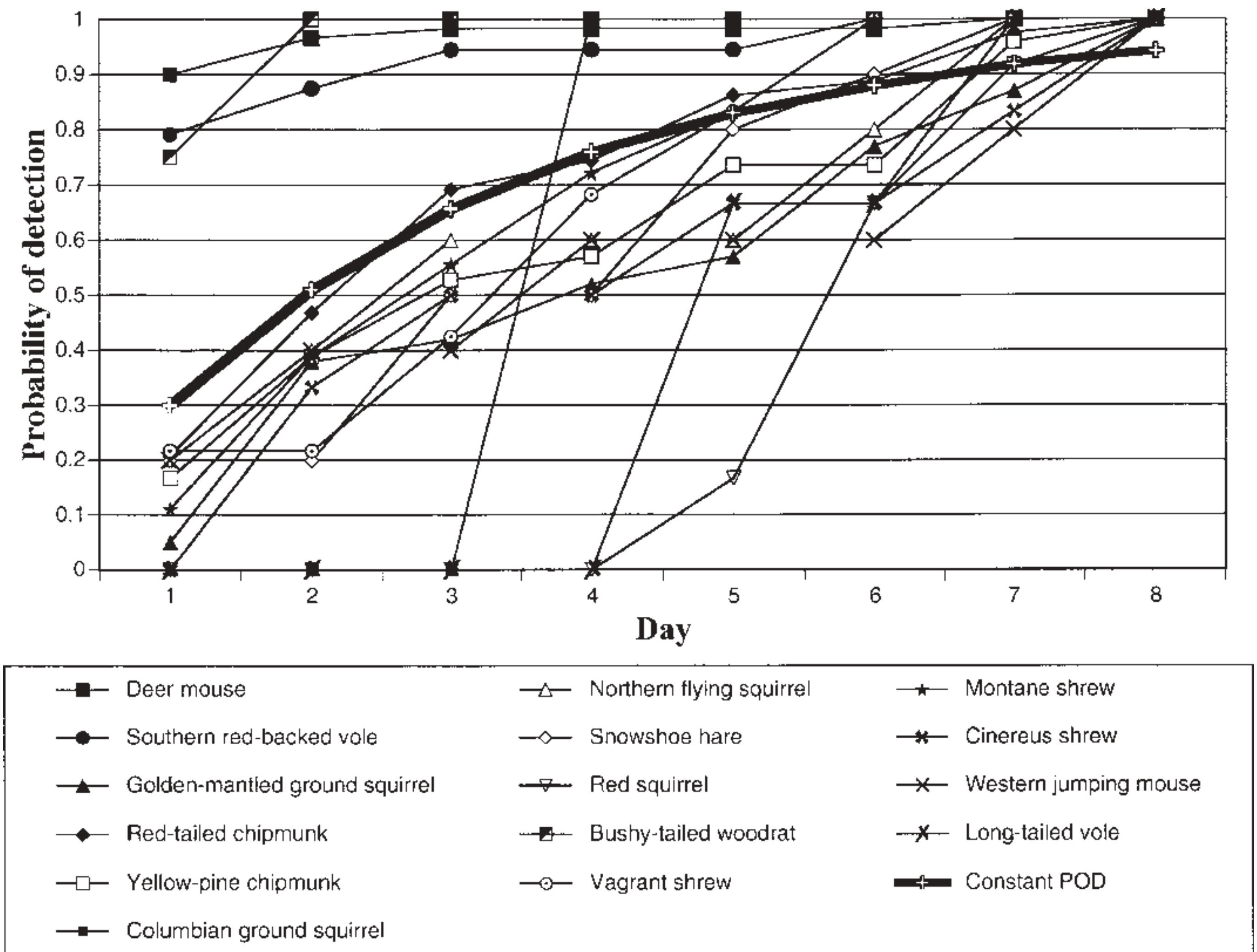


Figure 1—Cumulative probability of detection (POD) for 15 species of small mammals captured in ponderosa pine and western larch habitats of west-central Montana. The distributions in the middle of the chart generally follow expectation as can be seen by comparing their shapes to the expected constant POD. Species with an initial POD of zero and high latency to detection appeared to deviate from the constant POD model due to trap-negative behavioral responses.

responses. For instance, positive deviation from this model suggests "trap-positive" species or species that exhibit an affinity for traps, whereas negative deviations from this model indicate "trap-negative" species or species that initially avoid traps, and then rapidly habituate to them. Understanding these behavioral responses can provide a working model for identifying species that lend themselves to presence/absence sampling versus those that are likely to defy this sampling approach. For example, northern bog lemmings (*Synaptomys borealis*) are associated with rare bog and fen habitats and are classified as sensitive species on several National Forests in Region 1 (Pearson 1999). Although this animal could serve as a good indicator species to monitor for the health of these habitats, it is not readily live trapped and, therefore, does not lend itself well to presence/absence sampling using standard live trapping methods. However, other methods such as tracking stations or fecal tracking boards may produce higher POD for species that exhibit initial trap avoidance, thereby increasing the proportion of the community sampled within the first or second sampling day and decreasing the detection errors for those species with low POD.

Additional assumptions necessary to use POD to determine habitat associations and monitor distributional changes in species over time include the assumptions of constant POD among habitats and among years. For the five species of small mammals for which we had sufficient data to test these hypotheses, we found that after accounting for differences between years and habitats due to relative abundance, POD did not differ between habitats, and POD differed between years only for the red-tailed chipmunk. Therefore, we conclude that within this study POD was relatively constant between habitats and between years. However, we caution that for some species POD may differ among years, as it did for the red-tailed chipmunk, and that testing for constant POD among habitats should be repeated for other habitats and other species before it is assumed to be constant among habitats in general.

As POD appears to be essentially an index of abundance (relative abundance was a significant variable in logistic regression analyses for four of five species) that is robust to variation among years and habitats, it may eventually prove to be an effective monitoring tool. However, a good deal more work must be done to test the assumptions underlying the use of POD before implementing presence/absence sampling for monitoring wildlife populations. In particular, a better understanding of the relationship between POD and abundance will be critical to the application of presence/absence techniques for monitoring (see discussions in Thompson and others 1998; and Hayek and Buzas 1997).

Acknowledgments

We thank Kevin McKelvey and Tom Thompson for valuable reviews of this paper.

References

Azuma, D.L.; Baldwin, J.A.; Noon, B.R. 1990. Estimating the occupancy of spotted owl habitat areas by sampling and adjusting for bias. Gen. Tech. Rep. PSW-124. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 9 p.

Hayek, L.C.; Buzas, M.A. 1997. Surveying natural populations. New York: Columbia University Press. 563 p.

Pearson, D.E. 1999. Small mammals of the Bitterroot National Forest: a literature review and annotated bibliography. Gen. Tech. Rep. RMRS-GTR-25. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 63 p.

Thompson, W.L.; White, G.C.; Gowan, C. 1998. Monitoring vertebrate populations. San Diego, CA: Academic Press Inc. 365 p.

Verner, J. 1983. An integrated system for monitoring wildlife on the Sierra National Forest. Transactions of the North American Wildlife Natural Resources Conference. 48: 355-366.

Zielinski, W.J.; Kucera, T.E.; Barrett, R.H. 1995. Current distribution of the fisher, *Martes pennanti*, in California. California Fish and Game. 81(3): 104-112.

Zielinski, W.J.; Stauffer, H.B. 1996. Monitoring *Martes* populations in California: survey design and power analysis. Ecological Applications. 6(4): 1254-1267.

Small Mammals of the Bitterroot National Forest: Ecological Significance and Guidelines for Management

Dean E. Pearson

Abstract—Small mammal literature was reviewed to assess the ecological role of small mammals on the Bitterroot National Forest of western Montana. Small mammals fulfill numerous important roles in forest ecosystems by supporting a wide range of predators, dispersing seeds and mycorrhizal spores, altering vegetation through herbivory and seed predation, and preying on insects. Coarse woody debris (CWD) is among the most important habitat components for forest small mammals. Guidelines are suggested for managing CWD for small mammal populations with an emphasis on CWD recruitment.

The Bitterroot National Forest (Bitterroot Forest) initiated the Bitterroot Ecosystem Management Research Project (BEMRP) to develop an ecosystem-level approach to restoring forests altered by fire suppression and timber harvest. Low- to mid-elevation habitats on the Bitterroot Forest were historically dominated by park-like ponderosa pine (*Pinus ponderosa*) and ponderosa pine-western larch (*Larix occidentalis*) cover types, which were maintained by frequent, low-intensity fires (Arno 1976). Fire suppression and timber harvest have encouraged the encroachment of dense stands of Douglas-fir (*Pseudotsuga menziesii*) and grand fir (*Abies grandis*). Overcrowded stands and ensuing competition for limited resources has increased the susceptibility of these forests to disease, insect infestations, and high intensity, stand-replacing fire. By reintroducing periodic, low intensity fire in conjunction with thinning methods, researchers and managers seek to reestablish fire-dependent communities to pre-settlement conditions, thereby increasing forest health.

Literature was reviewed to develop a small mammal species list for the Bitterroot Forest and assess potential effects of proposed Ecosystem Management (EM) on small mammal communities, the predators they support, and the roles they play in forest ecosystems (Pearson 1999a). I sought distribution records from the Montana Natural Heritage Program Element Occurrence database, and reviewed published species' distributions and surveys conducted within the Bitterroot Valley for those families most commonly recognized as comprising the North American small mammals. Those families are shrews (Soricidae); moles (Talpidae); pikas (Ochotonidae); squirrels (Sciuridae); pocket gophers (Geomyidae); heteromyids (Heteromyidae); mice, rats, and voles (Muridae); and jumping mice (Zapodidae). I also included all families of bats (Order Chiroptera) and one species from the rabbit family (Leporidae), the snowshoe hare (*Lepus americanus*).

Forty-one species of small mammals were identified as occurring on, or likely to occur on, the Bitterroot Forest. Four species of bats, two species of shrews, and the northern bog lemming (*Synaptomys borealis*) were ranked by the Montana Natural Heritage Program as species of special concern at the state level. Pearson (1999a) reviewed the conservation status and provides brief management guidelines for each species of special concern.

Although early research on forest small mammals arose from concerns over the potentially deleterious impacts of small mammals' seed predation (Tevis 1956), researchers now recognize that small mammals play significant positive roles in forest ecosystems such as dispersers of seeds (Abbott and Quink 1970) and mycorrhizal spores (Maser and others 1978), predators of important forest insect pests (Holling 1959; Smith 1985; Andersen and Folk 1993), and prey base for rare and sensitive forest carnivores (Ruggiero and others 1994).

Insectivory is an important, but often overlooked role that small mammals play in ecosystems. For instance, deer mice (*Peromyscus maniculatus*), white-footed mice (*P. leucopus*), and shrews may help control important forest pests such as pine sawflies (*Neodiprion sertifer*), gypsy moths (*Lymantria dispar*), and acorn weevils (*Curculio* spp.) (Holling 1959; Smith 1985; Andersen and Folk 1993), and cinereus shrews (*Sorex cinereus*) can function as keystone predators that increase arthropod diversity by depredating dominant insects (Platt and Blakley 1973). However, small mammals can also heavily depredate beneficial insects such as the gall flies (*Urophora* spp.) released for the biological control of spotted knapweed (*Centaurea maculosa*) (Pearson and others 2000; Pearson 1999b). Based on laboratory feeding trials, Pearson and others (2000) showed that deer mice could consume nearly 1,200 larvae/mouse/day, illustrating the great predatory potential of small mammals on insects.

In addition to functioning as prey for sensitive species of forest carnivores and raptors, some small mammals also play important indirect roles in supporting some of these species. For instance, red squirrel middens provide rest sites (Buskirk 1984) and den sites (Ruggiero and others 1998) for American martens (*Martes americana*), and martens use middens to access subnivean prey at times when winter snows would otherwise prevent predators from reaching small mammals (Sherburne and Bissonette 1993). Yet red squirrels generally comprise <10 percent of marten diets (Buskirk and Ruggiero 1994). This situation has prompted

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Dean E. Pearson is a Wildlife Biologist, Wildlife Habitat Relationships Unit, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 8089, Missoula, MT 59807 U.S.A., e-mail: dpearson@fs.fed.us

researchers to suggest that a symbiotic relationship may exist between these species in western North America (Buskirk and Ruggiero 1994; Buskirk 1984).

Small mammals clearly play important roles in forest ecosystems. As a result, if "Ecosystem Management" is to succeed as such, the potential effects of management practices on small mammals and the processes dependent upon them must be considered. Since wildlife management is habitat management, we must first understand small mammal habitat associations in order to understand potential effects of EM on small mammal communities.

Because fire and timber harvest function as forms of disturbance in forest communities that generally reinitiate succession, habitat alterations resulting from EM can best be thought of as degrees of movement along the successional gradient. For instance, a clearcut or stand-replacing fire will completely reinitialize the process of secondary succession whereas selective cutting or a windstorm causing sporadic blowdown will initiate fine-scale succession within canopy openings. In the Northern Rocky Mountains, secondary succession progresses from grasses and forbs, to shrubs, saplings, young forest, and mature forest. If the stand continues to mature without disturbance, old-growth characteristics such as large diameter trees and snags and large diameter logs will develop.

Small mammals can also be tied to stages of plant succession to develop a Small Mammal Succession Model (SMSM). For instance, montane (*Microtus montanus*), long-tailed (*M. longicaudus*), and meadow (*M. pennsylvanicus*) voles associate primarily with the earliest grass and forb stages, whereas red-backed voles (*Clethrionomys gapperi*) and northern flying squirrels (*Glaucomys sabrinus*) reside within climax and old-growth forest. Chipmunks (*Tamias* spp.) favor shrubs that dominate early seral stages, red squirrels (*Tamiasciurus hudsonicus*) are linked to mature forest, and deer mice occur anywhere along the gradient.

As vegetation predictably responds to the successional process at multiple spatial scales, so do small mammals. For example, if we apply our understandings of forest succession and the SMSM to EM in ponderosa pine stands heavily invaded by Douglas-fir, we might expect low densities of grasses, forbs, and shrubs due to excessive shading beneath Douglas-fir thickets. At the microhabitat scale, small mammals may be depauperate within such Douglas-fir thickets. Deer mice may use these habitats by foraging for seeds and insects, red-backed voles may survive on truffles and seeds, and shrews may forage for insects in the litter, but the habitat will not be highly productive. Within the landscape, such thickets may actually add to the overall species richness because red-backed voles and shrews are rare to absent from the dry ponderosa pine parks without the input of these shady, moist habitats. Removal of Douglas-fir thickets would therefore probably increase small mammal abundance and diversity within the former thicket due to the increased use by deer mice and addition of chipmunks, golden-mantled ground squirrels (*Spermophilus columbianus*), and possibly *Microtus* resulting from increased grasses, forbs, and shrubs. In contrast, the potential loss of red-backed voles and shrews could decrease diversity at the stand level.

Although the Small Mammal Successional Model may provide a good rule of thumb for the direct effects of management on small mammals, managers must keep in mind that indirect effects may disassociate small mammals from their expected habitats through complex interactions. For instance, if opening of the canopy through selective cutting increases the presence of generalist predators such as coyotes (*Canus latrans*) and great-horned owls (*Bubo virginianus*), such sights could become sink habitats (e.g., Van Horne 1983) or predator pits for small mammal populations that might otherwise be expected to increase in response to treatment. This is especially true if features such as logs that can mediate predation by providing hiding and escape cover are also removed or destroyed in the process of timber harvest.

The Small Mammal Successional Model also highlights the fact that many small mammal habitat features are ephemeral. For instance, meadow voles are associated with grass and forb habitats, which can easily be generated by timber harvesting, but disappear rapidly as trees regenerate. To the extent that much of the current focus of EM within the Bitterroot Forest is on reestablishing park-like ponderosa pine and western larch forests by reinstating high frequency, low intensity fire, such ephemeral habitats can be maintained and small mammals are likely to respond to these treatments in a manner predicted by the Small Mammal Succession Model. However, more persistent features of small mammal habitats may be easier to manage successfully.

Coarse woody debris, primarily logs, is a persistent feature in forest systems that is important to many forest small mammals for hiding and escape cover, den sites, travel corridors, and feeding areas (Pearson 1999a). Coarse woody debris is also at the heart of many forest-floor ecosystem functions. It facilitates predator-prey interactions in winter by providing predators such as martens and weasels (*Mustela* spp.) access to subnivean small mammals. At other times, CWD functions to mediate predator-prey interactions by providing small mammals with hiding and escape cover, thereby potentially dampening small mammal population cycles and stabilizing predator communities (Pearson 1999a). Coarse woody debris provides midden sites for red squirrels, which in turn provide critical den sites and resting sites for marten. Coarse woody debris functions more directly in nutrient cycling and soil development (Harmon and others 1986), as nurse logs in moist forest systems (Harmon and others 1986), and possibly as fruiting sites for hypogenous mycorrhizal fungi (Amaranthus and others 1994). Therefore, CWD management supports not only small mammal communities, but processes integral to forest ecosystems.

Although CWD guidelines have been proposed for conservation of mycorrhizal fungi, cavity nesting birds, and small mammals (Carey and Johnson 1995; Harvey and others 1987; Thomas and others 1979), guidelines developed to date are subject to the following criticisms: (1) they do not address CWD recruitment; (2) they do not take into account CWD productivity based on the cover type, aspect, temperature, moisture, and other site-specific determinants; and (3) they do not provide for a diverse array of CWD size classes, decay classes, and other attributes important to small mammals and other CWD-associated wildlife.

In response to these shortfalls, I have proposed a relatively simple "within-treatment" coarse filter approach that could be developed to manage for CWD on the Bitterroot

Forest and in the Northern Rockies, based on an understanding of the site-specific nature of CWD recruitment. The logic is as follows. In natural systems, dead trees become CWD. Many become snags first. The amount of CWD on a site is determined by the number and size of trees produced there, which is a function of temperature, moisture, soils, and other site-specific factors. A ponderosa pine savanna will have fewer stems, but of larger diameter, than a dry-site lodgepole pine stand (Harris 1999). Moist-site lodgepole pine will produce more stems of larger diameter, than dry-site lodgepole, but logs may decay faster. Therefore, production of CWD is cover-type- and site-specific (Harris 1999; Brown and See 1981). Rates of transfer from trees to snags and CWD are also site-specific, being a function of probabilities of mortality events on a site.

An effective long-term management strategy should generate CWD based on cover type and local conditions. Furthermore, distributions for CWD attributes (diameter, decay, etc.) should reflect natural distributions. These goals could be achieved by randomly assigning a portion of each tree species/cohort combination in a treatment unit to CWD recruitment. Proportions could reflect current tree composition or future tree composition based on long-term goals. For instance, in a stand of 30 ponderosa pine and 70 Douglas-fir trees a goal of 20 percent CWD recruitment would result in 20 trees being assigned to CWD recruitment. These 20 trees could be assigned to species classes based on their proportional occurrence (in other words, 30 percent ponderosa pine, 70 percent Douglas-fir) or all 20 could be assigned to ponderosa pine if the long-term objective is to reestablish a ponderosa pine-dominant overstory. In this manner, species composition of CWD would more quickly come to reflect that of the overstory species. Coarse woody debris recruitment must be applied to each cohort in multistory stands to provide for continuous recruitment as occurs in natural systems. Ideas of CWD dispersion and management priority areas can also be built into this approach, and adaptive management should guide a CWD management strategy so it can mature over time based on new research information.

Acknowledgments

I thank Yvette Ortega and Tom Thompson for valuable reviews of this paper.

References

Abbott, H.G.; Quink, T.F. 1970. Ecology of eastern white pine seed caches made by small forest mammals. Ecology. 51: 271-278.

Amaranthus, M.; Trappe, J.M.; Bednar, L.; Arthur, D. 1994. Hypogeal fungal production in mature Douglas-fir forest fragments and surrounding plantations and its relation to coarse woody debris and animal mycophagy. Canadian Journal of Forest Research. 24: 2157-2165.

Andersen, D.C.; Folk, M.L. 1993. *Blarina brevicauda* and *Peromyscus leucopus* reduce overwinter survivorship of acorn weevils in an Indiana hardwood forest. Journal of Mammalogy. 74(3): 656-664.

Arno, S.F. 1976. The historical role of fire on the Bitterroot National Forest. Res. Pap. INT-187. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 29 p.

Brown, J.K.; See, T.E. 1981. Downed dead woody fuel and biomass in the Northern Rocky Mountains. Gen. Tech. Rep. INT-117. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 19 p.

Buskirk, S.W. 1984. Seasonal use of resting sites by marten in south-central Alaska. Journal of Wildlife Management. 48(3): 950-953.

Buskirk, S.W.; Ruggiero, L.F. 1994. American marten. In: Ruggiero, L.F.; Aubry, K.B.; Buskirk, S.W.; Lyon, L.J.; Zielinski, W.J., eds. The scientific basis for conserving carnivores: American marten, fisher, lynx, and wolverine. Gen. Tech. Rep. RM-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 7-37.

Carey, A.B.; Johnson, M.L. 1995. Small mammals in managed, naturally young, and old growth forests. Ecological Applications. 5(2): 336-352.

Harmon, M.E.; Franklin, J. F.; Swanson, F.J.; [and others]. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research. 15: 133-302.

Harris, R.B. 1999. Abundance and characteristics of snags in western Montana Forests. Gen. Tech. Rep. GTR-RMRS-31.Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 19 p.

Harvey, A.E., Jurgensen, M.F.; Larsen, M.J.; Graham, R.T. 1987. Decaying organic materials and soil quality in the inland Northwest: a management opportunity. Gen. Tech. Rep. GTR-INT-225. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 15 p.

Holling, C.S. 1959. The components of predation as revealed by a study of small mammal predation of the European sawfly. Canadian Entomologist. 91: 293-320.

Maser, C.; Trappe, J.M.; Nussbaum, R.A. 1978. Fungal small mammal interrelationships with emphasis on Oregon coniferous forests. Ecology. 59(4): 799-809.

Pearson, D.E. 1999a. Small mammals of the Bitterroot National Forest: a literature review and annotated bibliography. Gen. Tech. Rep. RMRS-GTR-25. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 63 p.

Pearson, D.E. 1999b. Deer Mouse Predation on the Biological Control Agent, *Urophora* spp., Introduced to Control Spotted Knapweed. Northwestern Naturalist. 80(1): 26-29.

Pearson, D.E.; McKelvey, K.S.; Ruggiero, L.F. 2000. Indirect effects of biological control agents released to control spotted knapweed. Oecologia. 122: 121-128.

Platt, W.J.; Blakley, N.R. 1973. Short-term effects of shrew predation upon invertebrate prey. Proceedings of the Iowa Academy of Science. 80: 60-66.

Ruggiero, L.F.; Pearson, D.E.; Henry, S.E. 1998. Characteristics of American marten den sites in Wyoming. Journal of Wildlife Management. 62(2): 663-673.

Ruggiero, L.F.; Aubry, K.B.; Buskirk, S.W.; Lyon, L.J.; Zielinski, W.J., eds. The scientific basis for conserving carnivores: American marten, fisher, lynx, and wolverine. Gen. Tech. Rep. RM-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment. 184 p.

Sherburne, S.S.; Bissonette, J.A. 1993. Squirrel middens influence marten (*Martes americana*) use of subnivian access points. American Midland Naturalist. 129: 204-207.

Smith, H.R. 1985. Wildlife and the gypsy moth. Wildlife Society Bulletin. 13: 166-174.

Tevis, L. Jr. 1956. Responses of small mammal populations to logging of Douglas-fir. Journal of Mammalogy. 37(2): 189-196.

Thomas, J.W.; Anderson, R.G.; Maser, C.; Bull, E.L. 1979. Snags. In: Thomas, W.J., tech. ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 60-77.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management. 47(4): 893-901.

The Effect of Time Period on Point Count Methodology for Monitoring Breeding Birds

Sallie J. Hejl
Thomas G. Thompson

Abstract—The traditional time period to survey breeding birds in low elevation forests of western Montana is from the middle of May through early July. There are some bird species, however, that begin their breeding cycle before these surveys begin and, therefore, may not be as vocal or active during the traditional survey period. To study the impact of survey timing on our understanding of the breeding bird community, we undertook a two year study of breeding birds in old-growth ponderosa pine (*Pinus ponderosa*) habitat in western Montana in 1996 and 1997. We chose eight sites and sampled each site with a transect of 5 points, 200 meters apart using standard bird point count methodology (Ralph and others 1995). Observers visited each site a total of ten times each year from mid- to late April until the end of June and recorded the number of each species seen or heard at each point on the transect. Over the two years, a total of 52 species and 6,730 individuals were detected within 100 meters of the counting points. The highest numbers of individuals and species were generally detected during the traditional survey period, confirming this time period as the best for surveying breeding birds in this habitat in western Montana. However, some resident and short distance migratory species were detected more frequently during the first five visits, indicating that they may be underrepresented in point count surveys beginning in mid-May. We also demonstrate that the use of habitat by flocking species may not be represented accurately in a single year's survey.

Controversies about National Forest management have underscored the need for better information on local animal and plant populations. Because they are more visible and therefore more familiar than other animal groups, birds have figured prominently in recent public debates over forest management policies. The existence of large nationwide surveys such as the Breeding Bird Survey (Robbins and others 1986), and numerous regional and statewide surveys, give biologists and managers important large-scale information about the status of avian populations. However, data from these large-scale surveys do not meet the increasing need for avian population trend and habitat association information at local and regional scales. Additional monitoring needs exist on a local level, where land managers require more specific information about species distributions, critical habitats, and the effects of management activities (Howe and others 1995).

Point counts are a widely used, relatively standardized method to sample bird populations for estimating densities in local areas, determining trends in populations over local and regional areas, assessing habitat preferences, and other scientific and population monitoring purposes (Johnson 1995; Ralph and others 1995). Moreover, point counts are well suited for avian population monitoring programs because they are straightforward methodologically and permit sampling at numerous geographic sites (Wolf and others 1995). Point counts depend on the observers' ability to detect and identify birds that are present in an area by sight and sound (song, call, or drum), because the majority of the detections of birds in forested habitats are made by sounds alone.

It is the hope of biologists that data recorded using the point count methodology is strongly correlated with the actual population of birds in the study area (Johnson 1995). Invariably, however, there are birds present at point count locations that are not detected, and this proportion of undetected birds is unknown and variable (Barker and Sauer 1995). This leads directly to the idea of detection probability, or the probability that a specific bird will be detected on a particular point count. This probability of detection varies by species, habitat, time of year, and a host of environmental factors, including temperature, weather, etc. (Ralph and Scott 1981). This greatly complicates comparisons of point count values between species, habitats, and even sites within a habitat. Therefore, biologists, seeking to minimize the effects of the variable probabilities of detection, have sought to limit census periods to times of "acceptable" field conditions (Burnham 1981) that are comparable between sites.

Somewhat overlooked in the literature on point count methodology is the influence of limiting the time period in which counts are conducted on the final results (but see Anderson and others 1981; Best 1981; Ralph 1981; and Skirven 1981). The optimal period for detecting species is when they are most vocal, usually when they are establishing and defending breeding territories, because many species are relatively quiet during incubation and nestling periods. Most local biologists and managers schedule point count surveys to take advantage of the best local time period for the majority of the breeding bird activity, meaning that they must wait for migratory birds to arrive. Hence, the typical breeding bird point count survey in this habitat in Montana begins in mid- to late May and ends by early July. However, some nonmigratory or short distance migrant species may be missed or underestimated by surveys that target the migratory species because the less migratory species establish territories and breed before long

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Sallie J. Hejl was a Research Wildlife Biologist and Thomas G. Thompson was a Wildlife Biologist, Wildlife Habitat Relationships Unit, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 8089, Missoula, MT during most of this project. Sallie J. Hejl is currently Assistant Professor, Wildlife and Fisheries Sciences, Texas A&M University, 2258 TAMU, College Station, TX 77843-2258. Thomas G. Thompson is currently GIS Specialist, Fire Effects Unit, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 8089, Missoula, MT 59807.

distance migrants return. This group of species includes a number of sensitive species such as forest owls (e.g., Northern Pygmy-owl; see table 1 for scientific names), woodpeckers, and other cavity nesters. Because many of these species are sensitive to habitat changes such as logging in National Forests of the Northwest (Hejl 1994; Hejl and others 1995), understanding these sampling biases is critical for effective forest management.

Table 1—Species observed in old-growth ponderosa pine categorized by detection frequency. More frequent early indicates this species was detected more frequently during the early visits than the traditional survey visits. More frequent later indicates more detections during the traditional survey period than earlier. Migration status, R = Residents, B = short distance migrants, and A = long distance migrants (follows Hejl and others 1995).

Species		More frequent early		More frequent later		No difference		Migration
Common Name	**Scientific Name**	**1996**	**1997**	**1996**	**1997**	**1996**	**1997**	**status**
Cooper's Hawk	*Accipiter cooperii*		X			X		B
Red-tailed Hawk	*Buteo jamaicensis*			X	X			B
American Kestrel	*Falco sparverius*			X				B
Blue Grouse	*Dendragapus obscurus*		X	X				R
Ruffed Grouse	*Bonasa umbellus*	X	X					R
Northern Pygmy-Owl	*Glaucidium gnoma*						X	R
White-throated Swift	*Aeronautes saxatalis*				X			A
Calliope Hummingbird	*Stellula calliope*				X			A
Red-naped Sapsucker	*Sphyrapicus nuchalis*	X	X					B
Williamson's Sapsucker	*Sphyrapicus thyroideus*	X			X			B
Hairy Woodpecker	*Picoides villosus*					X	X	R
Three-toed Woodpecker	*Picoides tridactylus*		X	X				R
Black-backed Woodpecker	*Picoides arcticus*						X	R
Northern Flicker	*Colaptes auratus*			X	X			B
Pileated Woodpecker	*Dryocopus pileatus*			X			X	R
Olive-sided Flycatcher	*Contopus cooperi*			X				A
Hammond's Flycatcher	*Empidonax hammondii*			X	X			A
Dusky Flycatcher	*Empidonax oberholseri*			X	X			A
Gray Jay	*Perisoreus canadensis*			X	X			R
Steller's Jay	*Cyanocitta stelleri*	X			X			R
Clark's Nutcracker	*Nucifraga columbiana*	X			X			R
Common Raven	*Corvus corax*	X					X	R
Black-capped Chickadee	*Poecile atricapillus*					X	X	R
Mountain Chickadee	*Poecile gambeli*					X	X	R
Chestnut-backed Chickadee	*Poecile rufescens*				X			R
Red-breasted Nuthatch	*Sitta canadensis*					X	X	R
White-breasted Nuthatch	*Sitta carolinensis*				X	X		R
Brown Creeper	*Certhia americana*			X	X			B
Winter Wren	*Troglodytes troglodytes*	X					X	R
Golden-crowned Kinglet	*Regulus satrapa*	X			X			R
Ruby-crowned Kinglet	*Regulus calendula*		X	X				B
Townsend's Solitaire	*Myadestes townsendi*					X	X	B
Swainson's Thrush	*Catharus ustulatus*			X	X			A
Hermit Thrush	*Catharus guttatus*			X			X	B
American Robin	*Turdus migratorius*					X	X	B
Varied Thrush	*Ixoreus naevius*	X	X					R
Cassin's Vireo	*Vireo cassinii*			X	X			A
Warbling Vireo	*Vireo gilvus*			X	X			A
Orange-crowned Warbler	*Vermivora celata*	X						A
Yellow Warbler	*Dendroica petechia*			X				A
Yellow-rumped Warbler	*Dendroica coronata*			X	X			B
Townsend's Warbler	*Dendroica townsendi*			X			X	A
MacGillivray's Warbler	*Oporornis tolmiei*			X	X			A
Western Tanager	*Piranga ludoviciana*			X	X			A
Black-headed Grosbeak	*Pheucticus melanocephalus*			X	X			A
Lazuli Bunting	*Passerina amoena*				X			A
Chipping Sparrow	*Spizella passerina*			X	X			A
Song Sparrow	*Melospiza melodia*		X					B
Dark-eyed Junco	*Junco hyemalis*					X	X	B
Cassin's Finch	*Carpodacus cassinii*				X	X		B
Red Crossbill	*Loxia curvirostra*				X	X		R
Pine Siskin	*Carduelis pinus*				X	X		B
Evening Grosbeak	*Coccothraustes vespertinus*				X	X		R

This paper reports the results of a study in which point count surveys of birds in old-growth ponderosa pine (*Pinus ponderosa*) habitat began five weeks prior to the traditional point count survey in western Montana and continued through the traditional survey time period, which is completed by early July. The main objective was to determine the phenology of detection (when birds begin to call and end calling) over a breeding season. Other objectives included determining the number of visits needed to get an accurate assessment of species composition and relative abundances, and determining the probability of detection for species in this habitat in order to make sample size recommendations for future surveys in this habitat (Hejl and Thompson, in preparation).

Methods

Eight study sites were selected in old-growth ponderosa pine stands on the Bitterroot and Lolo National Forests in western Montana between 1,236 m and 1,649 m in elevation. Sites were at least 8 hectares in size and 200 meters wide, dominated by relatively undisturbed, homogeneous stands of ponderosa pine with old-growth characteristics (Hejl and Woods 1991). One transect was established at each study site, and consisted of 5 points located 200 m apart and at least 100 m from any large habitat discontinuity or stand edge. The bird community was sampled on these sites during the spring and summer of 1996 and 1997.

Two experienced bird watchers conducted bird point counts at 7 to 10 day intervals from April 15 until June 28 in 1996 and from April 21 until June 26 in 1997, resulting in 10 visits each year to each site. The observers differed between years. Point counts were completed at all study sites prior to beginning another survey cycle. The first five visits of each year will hereafter be referred to as the early survey period and the last five visits as the traditional survey period. The term "visit" represents one observer going to a site and recording information on a particular day. "Survey cycle" will refer to all visits to study sites during a particular 7 to 10 day period.

Observers conducted bird counts from one-half hour after dawn to 11:00 a.m. and each point was sampled for 10 minutes. Observers recorded all birds detected (seen, heard or flushed) while at a point. Information was recorded for each individual bird only once at each point, at the time and distance it was first noted. Data recorded included species, approximate distance from the observer (≤25 m, 26-50 m, 51-75 m, 76-100 m, >100m), sex (if known), breeding evidence, flock size, time interval during which the bird was noted (0-3 min., 3-5 min., 5-10 min), if the bird was a "repeat" sighting from an earlier point on the transect, and if the bird appeared to be "using" the habitat. Observers also separately recorded birds seen or heard while traveling to, from, and between points.

We conducted analyses using count data of birds within 100 m of the observer, excluding repeat sightings of individual birds. The number of species detected, number of individuals detected, species proportions, and other summary statistics were determined and summarized by point, site, visit, and year. Excluded from the analyses were observations that could not be verified at the species level, but were recorded by the observers as unknowns (for example, unknown woodpecker or unknown flycatcher).

Results

Over the two-year study, a total of 53 species were detected: 46 species and 4,408 individuals in 1996, and 49 species and 2,322 individuals in 1997. The total number of species detected per visit ranged from 20 to 34 in 1996 and from 18 to 35 in 1997. The total number of individuals detected per visit ranged from 352 to 551 in 1996 and from 125 to 342 in 1997. The primary reason for the higher counts in 1996 was the very large number of individuals of flocking species such as Red Crossbills, Pine Siskins and Evening Grosbeaks encountered in the early weeks of the survey. Excluding counts for these three species, 2,409 individuals were detected in 1996, very similar to the 1997 totals.

There were six species common enough to have been detected in each survey cycle of both years: Hairy Woodpecker, Mountain Chickadee, Red-breasted Nuthatch, Townsend's Solitaire, American Robin, and Dark-eyed Junco. Four species (American Kestrel, Olive-sided Flycatcher, Orange-crowned Warbler, and Yellow Warbler) uncommon in this habitat were detected in 1996 but not in 1997. Seven additional uncommon species (Northern Pygmy-owl, White-throated Swift, Calliope Hummingbird, Black-backed Woodpecker, Chestnut-backed Chickadee, Lazuli Bunting, and Song Sparrow) were detected in 1997 but not in 1996. In each year there were five species detected only once, and a total of eight species seen only once during the entire study.

For the first perspective of differences between early and traditional survey times, we looked at species detected in the early period only or detected in the traditional period only. In 1996, there were two species detected in the early survey period but not in the traditional survey period (Orange-crowned Warbler, Winter Wren) and 10 species detected in the traditional survey period but not earlier (table 1). In 1997, five species were detected in the early survey period but not in the traditional survey period (Blue Grouse, Cooper's Hawk, Red-tailed Hawk, Song Sparrow, and Three-toed Woodpecker) and nine species detected in the traditional survey period but not earlier.

As the next step, we summarized the frequency of detections by counting the number of times a species was detected in one survey period compared to the other survey period. Frequency data from 1996 show 10 species were detected more frequently in the early survey period, 23 detected more frequently in the traditional survey period, and 13 were detected with equal frequency in both survey periods (table 1). In 1997, there were nine species detected more frequently in the early survey period, 26 detected more frequently in the traditional period and 14 detected with equal frequency in both survey periods. In summary, 15 different species were detected more frequently in the early survey period in at least one year. Three species, the Ruffed Grouse, Red-naped Sapsucker, and Varied Thrush were detected more frequently in the early count period in both years of the study.

Looking at the frequency of detections at each site individually, in 1996 there was an average of 3.5 species (range 1 to 8) over the eight sites that were detected in the early period, but not detected in the traditional survey period. The species most often detected only in the early count period were Ruffed Grouse (4 sites), Clark's Nutcracker (3 sites), and Varied Thrush (3 sites). In 1997, there was an average of 4.9 species (range 2-8) per site detected in the early period but not detected in the traditional survey period. These species included Northern Flicker (3 sites), Winter Wren (3 sites), and the Ruby-crowned Kinglet (5 sites).

Discussion

Most species in ponderosa pine old-growth forests of western Montana were best detected during the traditional survey period, but some species were detected more often in the period just prior to the time of traditional breeding bird surveys. All of the earlier species are permanent residents or short-distance migrants that begin breeding activity earlier than long-distance migrants. Ruffed Grouse, Red-naped Sapsucker and the Varied Thrush were detected more often in the early counts in both years of the study and 12 others were detected more often in early counts in at least one year. Some of these 12 other species are uncommon in this habitat, for example, Cooper's Hawk, Winter Wren, Orange-crowned Warbler, and the Song Sparrow. Other species detected more often early in 1996 were common species such as the Stellar's Jay, Clark's Nutcracker, and Common Raven. This indicates that if the goal of the point count surveys is to determine which species are present in this habitat, then the traditional survey period is satisfactory for most species. However, if the goal is to attempt to link the number of individuals of a particular species detected to the density of that species in this habitat, or alternatively, to assess the importance of the habitat to a particular species, then limiting survey counts to the traditional survey period can lead to erroneous conclusions.

Many of the species that are detected more often in the early survey period are species of special concern because of potential negative effects of logging (Hejl 1994; Hejl and others 1995). Resident woodpeckers, in particular, are of concern to management because of their use of large snags (dead trees) for nesting and feeding sites. The Red-naped Sapsucker, Williamson's Sapsucker and Three-toed Woodpecker are difficult to detect using traditional point count methodology. Our results suggest that this may be because they establish territories early and begin breeding early; moreover, they occur at low population levels. In fact, Hejl and Woods (1991) noted few Red-naped Sapsuckers on these same study sites in 1989 to 1991 when they conducted a study comparing bird presence and abundance in old-growth and second-growth stands. We do not know if the birds were present but missed due to sampling during the traditional time period, or if few were present in those years. Based on our results, we recommend that scientists or managers with particular interest in these species should consider including early season samples in their surveys.

Comparing the species abundances between years, it is clear that Red Crossbills, Pine Siskins and Evening Grosbeaks made up a large percentage of the individuals detected in the early weeks of 1996. In 1997, the abundances of these species were not substantially different than other species. This exemplifies why studies carried out over multiple years are necessary. A study based only on data from 1996 might conclude that Red Crossbills, Pine Siskins and Evening Grosbeaks are quite abundant in this habitat. Conversely the 1997 data suggest that these species were no more or less abundant than several other species in this habitat. However, using data from both field seasons and including the early season data of the survey, it is clear that these species may utilize this habitat heavily at certain times and in certain years, and not as heavily at other times. These results indicate that old-growth ponderosa pine may be an important breeding and foraging habitat for these species during certain years. Therefore, the addition of early season counts to multiple-year surveys improves our ability to derive good estimates of these species for use in management plans and scientific studies.

Acknowledgments

Elizabeth Beringer, Amy Cilimburg, Theresa Ferraro, and Carol Snetsinger collected the bird observations and entered the data. Gary Slater helped with fieldwork and preliminary data analysis. Kevin McKelvey and Dean Pearson reviewed an earlier draft. This work was supported by the Bitterroot Ecosystem Management Research Project, Rocky Mountain Research Station, Forestry Sciences Laboratory, Missoula, MT. Thanks to all.

References

Anderson, B.W.; Ohmart, R.D.; Rice, J. 1981. Seasonal changes in avian densities and diversities. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 262-264.

Barker, R.J.; Sauer, J.R. 1995. Statistical aspects of point count sampling. In: Ralph, C.J.; Sauer, J.R.; Droege, S., tech. eds. Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture: 125-130.

Best, L.B. 1981. Seasonal changes in detection of individual bird species. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 252-261.

Burnham, K.P. 1981. Summarizing remarks: environmental influences. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 252-261.

Hejl, S.J. 1994. Human-induced changes in bird populations in coniferous forests in Western North America during the past 100 years. Studies in Avian Biology. 15: 232-246.

Hejl, S.J.; Woods, R.E. 1991. Bird assemblages in old-growth and rotation-aged Douglas-fir / ponderosa pine stands in the northern Rocky Mountains: a preliminary assessment. In: Baumgartner, D.M.; Lotan, J.E., eds. Interior Douglas-fir, the species and its management. Symposium Proceedings. Pullman, WA: Washington State University: 93-100.

Hejl, S.J.; Hutto, R.L.; Preston, C.R.; Finch, D.M. 1995. Effects of silvicultural treatments in the Rocky Mountains. In: Martin, T.E.; Finch, D.M., eds. Ecology and Management of Neotropical Migratory Birds: A Synthesis and Review of Critical Issues. New York: Oxford University Press: 220-244.

Howe, R.W.; Wolf, A.T.; Rinaldi, T. 1995. Monitoring birds in a regional landscape: lessons from the Nicolet National Forest bird survey. In: Ralph, C.J.; Sauer, J.R.; Droege, S., tech. eds. Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 83-92.

Johnson, D.H. 1995. Point counts of birds: what are we estimating? In Ralph, C.J.; Sauer, J.R.; Droege, S. tech. eds. Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 117-124.

Ralph, C.J. 1981. An investigation of the effect of seasonal activity levels on avian censuring. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 265-270.

Ralph, C.J.; Scott, J.M., eds. 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology. 630 p.

Ralph, C.J.; Droege, S.; Sauer, J.R. 1995. Managing and monitoring birds using point counts: standards and applications. In: Ralph, C.J.; Sauer, J.R.; Droege, S., tech. eds. Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 161-168.

Robbins, C.S.; Bystrak, D.; Geissler, P.H. 1986. The breeding bird survey: its first fifteen years, 1965-1979. Resour. Pub. 157. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service: 133-159.

Skirven, A.A. 1981. Effect of time of day and time of season on the number of observations and density estimates of breeding birds. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 271-274.

Wolf, A.T.; Howe, R.W.; Davis, G.J. 1995. Detectability of forest birds from stationary points in northern Wisconsin. In: Ralph, C.J.; Sauer, J.R.; Droege, S., tech. eds. Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 19-24.

Overview of Forest Carnivore Survey Efforts in the Bitterroot Mountains

Kerry R. Foresman

Abstract—Disturbance of forested habitats through natural or man-made causes is thought to adversely affect medium-sized carnivores such as the American marten (*Martes americana*), fisher (*Martes pennanti*), wolverine (*Gulo gulo*), and lynx (*Lynx lynx*). In order to recognize these impacts it is necessary to be able to accurately detect the presence of these species in both natural and disturbed habitats. This is made difficult by the very nature of these animals. They are secretive and, because they are carnivores, are generally found in low abundance. Over the past four years, I have helped develop standardized protocols for the detection of these and other species using remote cameras and tracking plates. Both of these methods are non-intrusive and provide presence/absence information. This research provides the framework for the census of rare species and will allow for the comparison of data obtained from different regions or states.

Over the past 20 years concerns have been raised about the effects which habitat disturbance may be having on populations of mid-sized forest carnivores. In the northwestern United States in particular, four such species, American marten (*Martes americana*), fisher (*Martes pennanti*), wolverine (*Gulo gulo*), and lynx (*Lynx lynx*), have been classified as "sensitive" species within one or more regions of the U.S. Forest Service (Ruggiero and others 1994). Although populations of such species are thought to be on the decline, little empirical evidence is available to support this conclusion and it is difficult to interpret available data since no consistency exists in the methodological approaches that have been employed across regions or states. In 1995, Zielinski and Kucera outlined standardized protocols for the detection of these species in a U.S. Forest Service General Technical Report. Their hope was not only to stimulate research in this area but, more importantly, to standardize the methods employed so that data collected could be shared throughout the northwest. I was asked to field-validate and modify these protocols, where necessary, so that a consistent research approach could be developed. My research began in the fall of 1994 and continues at the present time.

Five drainages of the Bitterroot Mountains (Bass Creek, Kootenai Creek, Big Creek, Sweathouse Creek, and Bear Creek) were chosen as study sites. This research was organized in three phases. The first phase, conducted from the fall of 1994 through the summer of 1995, involved a comparison of three proposed censusing methods and an analysis of the suggested standardized protocols for each (Foresman and Pearson 1995; Foresman and Pearson 1998). These methods were as follows: (1) the use of remote cameras, (2) the use of tracking plates (both covered and uncovered), and (3) snow tracking (Zielinski and Kucera 1995). The first of these methods, remote cameras, employs two types of detectors coupled to the camera. One detector can sense movement and the other can sense heat. Bait is placed at a camera station and when a warm-bodied animal moves into the field of the detector it is sensed and the camera to which the detector is coupled is triggered to take a picture (Kucera and Barrett 1993; Kucera and others 1995). Four remote cameras were placed in each of four drainages of the Bitterroots (covering a 20.72 km^2 sample area) from 30 November 1994 through 28 March 1995. Each camera station was maintained for 28 days. Cameras were checked at 4 to 7 day intervals; film, batteries, and bait were replaced as needed.

The second method used tracking plates, flat sheets of metal that have been carboned (sooted) with an acetylene torch and placed on the ground and baited (designated as uncovered plates). An animal steps on the carboned surface to obtain the bait and leaves a track impression on the surface. In some cases, the metal surface is protected against rain or snow with a Quonset hut cover (covered plates), and a sheet of white contact paper (sticky side up) is affixed to capture an animal's tracks (Zielinski 1995). Twelve tracking plates (six covered and six open) were placed in each of the five drainages, spaced approximately 0.54 km apart, to cover a 20.72 km^2 sample area. These surveys began on 24 April 1995 and ran through 5 June 1995. Stations were checked every other day for a total of 12 (in some cases 14) days. If tracks were noted they were removed for analysis, plates were recarboned, and the bait was freshened (Foresman and Pearson 1998).

The last method, that of snow tracking, was attempted during the winter and spring of 1995 but prevailing snow conditions limited the usefulness of this method. Though some results were obtained they were not extensive enough from which to draw meaningful conclusions.

For a detailed analysis of this first phase of research refer to Foresman and Pearson (1998). An overview of the results obtained is as follows. Three of the four species of interest were detected by camera (American marten, fisher, and wolverine) and two of the four were detected by tracking plate (American marten and fisher). The mean latency to detection (LTD, average time from which a method was set to the time at which a species was detected) by camera was 13.5 ± 4.9 days (n = 8) for American marten, 9.0 ± 7.0 days (n = 2) for fisher, and 13 days (n = 1) for wolverine. LTD values for detection by covered track plate were 3.3 ± 0.4 days for American marten and 5.3 ± 1.8 days for fisher; for uncovered track plates this value was 2.3 ± 0.3 days for American marten. An LTD could not be determined for

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Kerry R. Foresman is a Professor, Division of Biological Sciences, University of Montana, Missoula, MT 59812.

fisher for uncovered track plates because rain prohibited accurate analyses. When these methods were compared for their effectiveness, ease of use, and accuracy of identification remote cameras ranked highest. However, tracking plates may be highly effective under certain circumstances.

Remote cameras have one additional, significant advantage over the other methods described here. Because they record the exact time at which an animal is detected they can provide data on activity patterns that cannot be obtained otherwise. Winter activity patterns of American marten and two of its primary prey species, snowshoe hares (*Lepus americanus*) and red squirrels (*Tamiasciurus hudsonicus*), were also investigated during the November/March time period (Foresman and Pearson 1999). Marten observations occurred randomly during daytime and nighttime hours (n = 85). Interestingly, 100 percent of the snowshoe hare observations (n = 25) occurred at night while red squirrels were diurnal (n = 22). This suggests that marten are able to take advantage of both prey species, as well as smaller rodent species that may be either diurnal or nocturnal.

The second phase of this research was conducted between January and July 1996 (Foresman and Maples 1996). Here the focus was to expand the use of remote cameras and tracking plates into additional habitat types as well as test tracking plates during different seasons (spring/summer versus. previous winter studies). Similar experimental designs were employed as previously described. Camera studies were conducted during the winter months. Again, three of the four target species (American marten, fisher, and wolverine) were detected by camera. Mean LTD values were similar to those previously recorded, 12.3 ± 9.5 days for American marten and 6.0 ± 3.7 days for fisher. The single wolverine detected during 1996 occurred four days after the camera station was set. Track plate studies began in May and continued through July. Only American marten were detected during this time period. LTD values ranged from two to thirteen days, depending on the habitat type. It was evident from this year's data that the tracking plate method is best employed during winter rather than spring/summer months. This appears to be a direct function of food availability for these carnivores.

The third phase of this research began in the fall of 1997 and continues at present. One Wildlife Biology graduate student, Jake Ivan, is attempting to determine "probability of detection" values (POD) for American marten using covered track plates (Ivan 1998). When a detection device like a camera or track plate is set out and does not detect the species of interest, it does not necessarily mean that that species is absent. The device has simply not detected it. There may be many reasons for failure to detect an animal even if it is present. The most likely of these is that the animal may be shy and unwilling to come close to an unusual object. To have a greater assurance that such detection methods work, we need to determine what the probability of detecting a given species by a particular method is, given that we indeed know that the animal is present. We have designed an experiment that will allow us to calculate POD values. Covered track plates are being set as previously described. Marten are then captured and radio collared. We then place a radio receiver next to the track plate and couple it to an antenna that encircles the track station. By adjusting the sensitivity of the receiver we can obtain radio detection of the collared marten if they come within ten meters of the plate. A data logger is also plugged into the receiver so that each individual detection, along with date and time information, is recorded (fig. 1). It can then be determined how often an individual animal comes close to the track plate (within visual range and able to smell the bait) but does not step on the plate and is not "officially" detected. This allows us to calculate the probability of detection. This procedure was used in three drainages during the past field season; additional drainages will be studied during the summer of 1999.

It is our hope that this research will allow us to develop accurate, efficient, relatively low-cost methods that can be used in a standardized manner so that field biologists across the northwest can begin collecting similar presence/absence data on these secretive forest carnivores.

Acknowledgments

I would like to thank two technicians, D. E. Pearsonº and M. Maples, and a graduate student, J. Ivan, for directing this field research, and K. R. Furrow, P. Ziegler, S. D. Tomson, and R. Berkley for assisting these researchers in the field. Funding was provided by The Rocky Mountain Research Station, U.S. Forest Service, Missoula, Montana and The University of Montana. Housing was provided by the Stevensville Ranger Station, Bitterroot National Forest, and D. Lockman's assistance was appreciated in this regard.

References

Foresman, K.R.; Maples, M.T. 1996. Application of remote sensing methods for the detection of forest carnivores and their prey base in Bitterroot National Forest. Missoula, MT: The University of Montana; Final Report for the Research Joint Venture Agreement. INT-97017-RJVA. 85 p.

Foresman, K.R.; Pearson, D.E. 1995. Testing of proposed survey methods for the detection of wolverine, lynx fisher, and American marten in Bitterroot National Forest. Missoula, MT: The University of Montana; Final Report for the Research Joint Venture Agreement. INT-94918-RJVA. 100 p.

Foresman, K.R.; Pearson, D.E. 1998. Comparison of proposed survey procedures for detection of forest carnivores. Journal of Wildlife Management. 62(4): 1217-1226.

Foresman, K.R.; Pearson, D.E. 1999. Activity patterns of American martens, *Martes americana*, snowshoe hares, *Lepus americanus*, and red squirrels, *Tamiasciurus americanus*, in westcentral Montana. The Canadian Field-Naturalist. 113(3): 386-389.

Ivan, J. 1998. Effectiveness of carbon-sooted aluminum track plates for detecting American marten. Missoula, MT: Wildlife Biology Program, University of Montana. 13 p. Thesis proposal.

Kucera, T.E.; Barrett, R.H. 1993. The Trailmaster camera system for detecting wildlife. Wildlife Society Bulletin. 21: 505-508.

Kucera, T.E.; Soukkala, A.M.; Zielinski, W.J. 1995. Photographic bait stations. In: Zielinski, W.J.; Kucera, T.E., tech. eds. American marten, fisher, lynx and wolverine: survey methods for their detections. Gen. Tech. Rep. PSW-GTR-157. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: Pages 25-65.

Ruggiero, L.F.; Aubry, K.B.; Buskirk, S.W.; Lyon, L.J.; Zielinski, W.J. 1994. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 184 p.

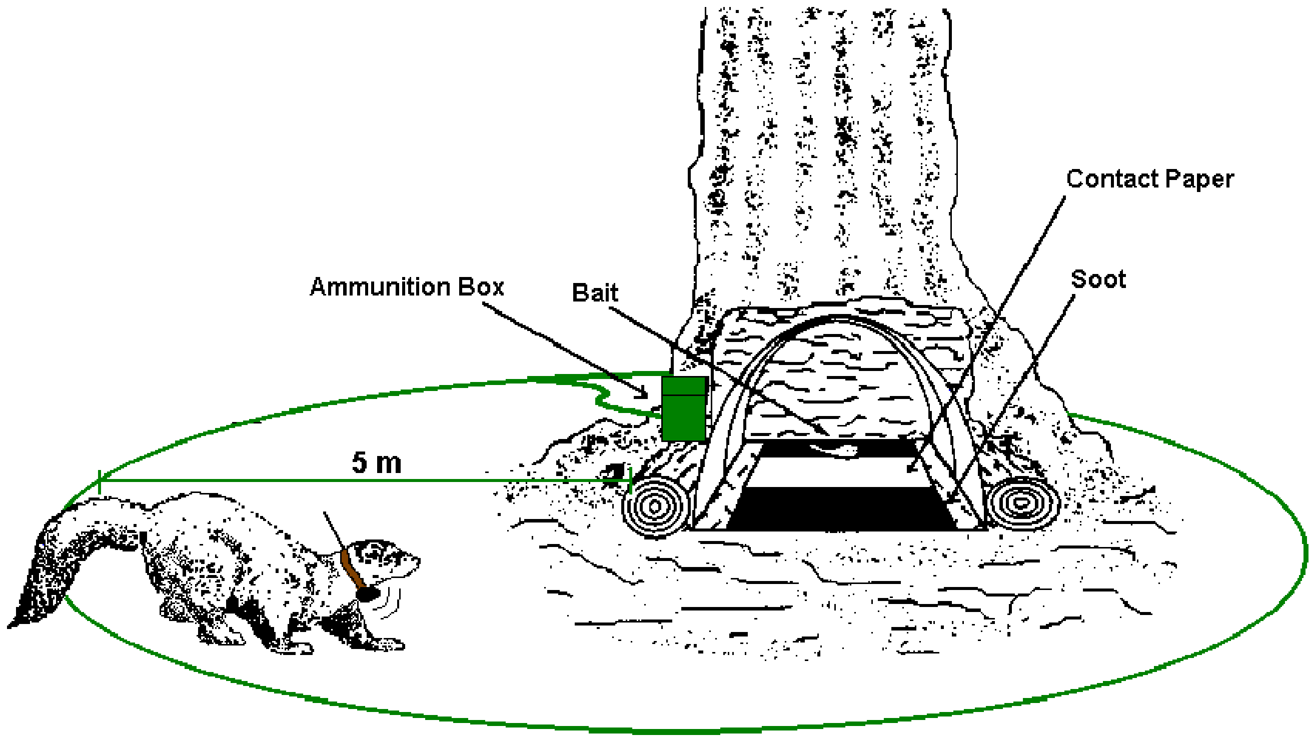


Figure 1—Experimental design for the determination of probability of detection (POD) values.

Zielinski, W.J. 1995. Track plates. In: Zielinski, W.J.; Kucera, T.E., tech. eds. American marten, fisher, lynx and wolverine: survey methods for their detections. Gen. Tech. Rep. PSW-GTR-157. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 67-89.

Zielinski, W.J.; Kucera, T.E., tech. eds. 1995. American marten, fisher, lynx and wolverine: survey methods for their detections. Gen. Tech. Rep. PSW-GTR-157. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research. 163 p.

3. Understanding the People and Their Relationship to the Ecosystem

At annual workshops, researchers present their findings and discuss projects with managers and members of the public. University of Montana Professor Carl Fiedler addresses the public at a workshop in Hamilton, MT.

Agencies Within Communities, Communities Within Ecosystems

Jane Kapler Smith
Kerry McMenus

Abstract—Can scientific information and intensive, extensive public involvement through facilitated meetings be expected to lead to agreement on natural resource issues? Communications and research in the Bitterroot Ecosystem Management Research Project indicate that, where people's values differ greatly, consensus is not a realistic goal for short term planning processes. Public involvement is successful when agreement is reached, but it is also successful when relationships among participants are enhanced, when all stakeholders are identified and included, and when public input is used to improve products such as management plans. While using public processes to accomplish planning goals, agencies must also continually work toward the long-term goals of increased participation, understanding, and acceptance. This process is enhanced by (1) accepting tensions within communities as forces that contribute to balanced decisions; (2) using the infrastructure and polity of the local community to involve the public and considering land management issues as extending across time, not resolved by single projects; (3) maintaining a commitment to obtaining, using, and sharing scientific knowledge; and (4) developing long-term relationships with community groups and members of the public, including newcomers. The long-term process of establishing and improving relationships with partners enhances short-term public involvement efforts to help agencies develop sound management plans and implement them on the ground.

If people have plenty of information that is scientifically based and plenty of opportunities to learn about one another and the environment, then they will eventually reach consensus on goals and practices for wildland management. This hypothesis captures the main focus of human dimensions activities in the Bitterroot Ecosystem Management Research Project (BEMRP) over the past five years. While this hypothesis was not explicitly stated at the outset, Gebhardt (1995) points out in his study of the history of public land management that a common expectation from Congress and public agencies is that managers will produce harmony among people who advocate competing resource uses. To investigate the premise that a well informed, well facilitated public involvement process leads to agreement among participants, BEMRP participated in planning for the 40,000-acre Stevensville West Central (SWC) area in the Bitterroot National Forest (described in Guthrie and Freimund 1996a). Scientists were deeply involved in this process; they gave presentations, hosted field trips, attended public meetings, and worked intensively with the interdisciplinary team. Planning for SWC began in January 1994; the final public meeting for review of alternatives occurred on January 31, 1996.

The intensive, science-based public involvement process used in SWC was just one of the human dimension goals articulated in BEMRP's master study plan (Carlson and others 1994). The others were to expand the Bitterroot National Forest's public awareness program, assess data describing the Bitterroot community, and study alternative approaches to public involvement.

In this paper, we summarize the ways in which BEMRP's human dimensions goals were addressed and use the results to test the "inform-and-agree" hypothesis stated above. "Hypothesis" is used here not as a tool for analysis of quantitative data but as a framework for synthesizing information already collected, "a tentative assumption made in order to draw out and test its logical or empirical consequences" (Webster's New Collegiate Dictionary 1975). First, we examine BEMRP's communications efforts and research regarding the first part of the hypothesis, providing up to date, high quality scientific information and opportunities for mutual learning. Second, we examine the project's work regarding the second part of the hypothesis, the consensus expected from greater understanding. Finally, we discuss alternatives to the "inform-and-agree" model. In each section, we identify key questions, summarize relevant BEMRP research, and then synthesize what we have learned.

Hypothesis, Part 1: Sharing Scientific Information and Opportunities to Learn

Key Questions

This section synthesizes what we have learned about two key questions: What is effective communication? and how do managers, scientists, and the public learn? Information provided for the public debate about the Stevensville West Central process was both "expert" (scientific and technical, usually provided by resource professionals and scientists) and "experiential" (personal experiences and values of all participants) (Guthrie 1997). (Table 1 lists BEMRP research projects relating to human dimensions.)

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Jane Kapler Smith is an Ecologist, Fire Effects Unit, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 8089, Missoula, MT 59807. Kerry McMenus is Group Leader for Inventory, Assessment, and Monitoring, USDA Forest Service, Northern Region, 200 East Broadway, Missoula, MT 59802.

Table 1—BEMRP Research on the social system, communications, and public involvement, including the Stevensville West Central (SWC) process.

Research subject	References
Description of SWC public involvement	
Stevensville West Central public involvement process	Guthrie and Freimund (1996a)
Evaluation of public involvement processes	
Literature review regarding public involvement	Gebhardt (1995)
Description and commentary on SWC process	Pukis (1997)
Success in SWC process	Guthrie (1997)
Consensus in SWC process	McCool and Guthrie (1998)
Alternative ways to involve public in planning	Richards and McLuskey (1997)
Effective communications	
Use of science and scientists in public involvement	Freimund (1998)
Effectiveness of educational trunk about wildland fire	Thomas and Walsh (2000)
Social assessment, public opinion, perceptions	
Social assessment of the Bitterroot	Canton-Thompson (1994)
Survey of public opinion	Menning (1995)
Tourism survey results relating to forest management	Freimund (1996)
Integrating information from social assessment and survey	Guthrie and Freimund (1996b)
Social science—general	
Synthesis of social science research	McCool (1998)

BEMRP Communication Activities and Research

If lack of scientific information is a barrier to agreement, then more, better information is needed. The research and modeling presented in these proceedings represent five years of ecological research; more than 50 studies about the ecosystem have been completed. They address vegetation dynamics, animal populations and habitat, and effects of potential management choices. While research has focused on the Bitterroot Valley, other areas throughout the Northern Region have also been included. This biophysical research and modeling provide the scientific basis for dialogue among scientists, managers, and the public.

Scientific information cannot contribute to management until it is shared. Fifteen public meetings, nine presentations, five field trips, and a potluck dinner provided opportunities for experiential learning and nurturing relationships among partners during the SWC public involvement process (Guthrie and Freimund 1996a). Additional field trips provided managers and the public with on-the-ground experience of research findings. Annual workshops have brought participants together to discuss research results (fig. 1). A report to partners, published annually in newsletter format, goes to scientists, managers, and hundreds of citizens in the Bitterroot Valley; it also goes to members of the public from 25 states outside Montana. The newsletter places scientific information, presented with a minimum of technical detail, in the hands of managers and citizens. The BEMRP Web site (**www.fs.fed.us/rm/ecopartner**) has enabled participants and others interested in ecosystem-based management to stay informed on research projects.

During the year following completion of the SWC environmental assessment, two BEMRP projects obtained information about participants' perceptions of the process. University of Montana graduate student Kathleen Guthrie interviewed 42 participants, including managers, researchers, and members of the public. She recorded their responses to questions about the content and conduct of the public meetings, the strengths and weaknesses of the process, its outcome, and its potential influence on future public involvement. Guthrie's interviews provided the data for subsequent analyses regarding communications (Freimund 1998), success in public involvement (Guthrie 1997), and consensus (McCool and others 2000). Concurrent with the Guthrie project, journalist Rick Pukis interviewed SWC participants and produced a videotape showing participants' perceptions of the process (Pukis 1997).

Figure 1—At annual workshops, researchers present their findings and discuss projects with managers and members of the public. University of Montana Professor Carl Fiedler addresses the public at a workshop in Hamilton, MT.

What We Have Learned

What is Effective Communication?—Although many authors recognize the importance of technology transfer and increasing public understanding for effective management (for example, Brunckhorst and Rollings 1999; U.S. Department of Agriculture, Forest Service 1995), there is less agreement on how to communicate effectively. We have learned the following things about effective communications in BEMRP: Brief information summaries, clear graphics, and visualizations provide a better basis for discussion than technical lectures (Freimund 1998). When people perceive that they are being excluded or manipulated, their learning is blocked (McCool 1998; McCool and others 2000), and use of technical language can create a perception of exclusion. Use of jargon forms barriers to public learning that should be avoided "at all costs" (Guthrie 1997). Two practical measures, in particular, have helped promote clear communications: (1) Researchers and managers critique one another's graphics and presentations prior to public workshops, and (2) a simple, jargon-free summary occurs at the beginning of every page on the Project's Web site.

How Do Managers, Scientists, and the Public Learn?—Managers and the public regard learning as more than a transfer of knowledge from "experts" to others; they see it as a two-way process (Guthrie 1997). In this process, managers and researchers share scientific information about ecosystems and management possibilities, and the public shares experiential knowledge and articulates values that are not described in scientific studies or technical models (Freimund 1998). An important aspect of this two-way learning is ability and willingness to listen actively as well as "tell." If participants do not agree that they can accept a proposed course of action, for instance, further data and technical explanations may not be as useful as further dialogue regarding participants' values (McCool and others 2000).

People learn best in the context of positive, trusting relationships, whether between participants in a public involvement process (Guthrie 1997) or between teachers and students (Thomas and Walsh 2000). Presentations, field trips, workshops, and public meetings provide opportunities for BEMRP partners to overcome stereotypes and develop positive relationships. Routine communications (newsletter and Web site) provide continuity for the learning process and ensure that new knowledge is readily available to all participants. Routine communications are an agency's demonstration of good faith in sharing information. They also enable managers to show partners how public input was used in planning.

Including scientists in public involvement not only provides expert information but also provides further opportunities for building relationships; in fact, the latter may be more valued than the former (Freimund 1998). Increased understanding of complex concepts, however, often occurs over the long term rather than being a quick, efficient process (Guthrie 1997). Efforts to enhance public understanding of scientific principles are a long-term investment in content and relationships even if they do not contribute substantially to a particular project. Rapid population growth and urbanization of rural areas like the Bitterroot Valley increase the difficulty of developing positive long-term relationships and increasing public understanding (McCool 1998); outreach specifically to newcomers is essential.

Educational theory indicates that first-hand experience and hands-on activities are particularly effective ways to learn new information (Lisowski and Disinger 1991). BEMRP's field trips provide technical information in a tangible, visible, on-the-ground context and provide an informal setting in which participants get to know each other better (fig. 2). Former Stevensville District Ranger Tom Wagner believes these field trips "have the most promise of dealing with the lack of public support for active management" in a forest (Wagner 1998). Effectiveness of hands-on learning is reported in Thomas and Walsh's (2000) assessment of *FireWorks*, an educational trunk and curriculum for students to use in learning about fire ecology. The assessment shows that information learned experientially in the classroom can be successfully applied in field settings. In addition, this kind of learning enhances students' perceptions of the teacher and the learning environment (fig. 3).

Figure 2—Field trips are provided for both professionals and the public. This field trip featured visits to three ponderosa pine sites where ecosystem-based management practices had been assessed in regard to aesthetic effects, fire hazard reduction, and economic feasibility.

Figure 3—Hands-on experiences increase learning and improve relationships. Middle school teachers from Thompson Falls, MT, learn about ladder fuels at a teacher workshop.

Hypothesis, Part 2: Reaching Consensus on Goals and Practices for Wildland Management

Key Questions

The "inform-and-agree" hypothesis suggests that understanding will lead to consensus regarding land management. It assumes that the success of public involvement is measured mainly by the extent to which agreement is reached. Research regarding public involvement in SWC provides information for addressing three key questions: What really is successful public involvement? How successful was the SWC public involvement process? Is consensus an appropriate goal for public involvement?

BEMRP Activities and Research

Interviews of SWC participants conducted by Kathleen Guthrie provided the basis for research about successful public involvement (Guthrie 1997) and the role of consensus in success (McCool and others 2000). Anecdotal information from videotape (Pukis 1997) supplemented these research findings.

What We Have Learned

What is Successful Public Involvement?—Forest Service mandates and public expectations focus largely on tangible ecological outcomes as indicators of success (U.S. Department of Agriculture, Forest Service 1995). In addition to this product-oriented definition of success, Congress and public agencies regard agreement among participants as a strong indicator of success (Gebhardt 1995). But success is not limited to agreement or actions taken (or not taken) "on the ground." Participants in the SWC process described success in many ways. In interviews with SWC participants, Guthrie (1997) identified eight aspects of success. They relate to:

- Products (the completion of a plan or task).
- Politics (the extent to which the process and plan are representative and accepted).
- Interests (the extent to which diverse interests are protected by the plan).
- Responsibility (the extent to which participants develop a sense of ownership).
- Relationship (occurring when relationships among stakeholders are established and enhanced).
- Learning (in which all participants learn about each other's experiences, needs and values).
- Education (in which managers and researchers share their expertise with the public).
- Implementation (indicated by resource protection on the ground).

Guthrie's first two aspects of success reflect the two common agency expectations of success: product completion and participant agreement. The remaining aspects are more difficult to measure, but they are vitally important for effective public involvement.

How Successful Was the Extensive SWC Public Involvement Process?—The complexity of "success," as described by Guthrie (1997), is reflected by the multi-faceted way in which SWC participants related to the public involvement process. In videotaped interviews (Pukis 1997), participants spoke about success in terms of the aspects that were important to them. Several focused on relationships in the group, with emphasis on the need for strong facilitation. A few were not satisfied with the process because they felt that the outcome did not support their interests. Former Stevensville District Ranger Leslie Weldon focused on learning: "We learned a lot about the values and concerns that the public has, in a different way than we have in the past" (Pukis 1997). The SWC process produced a plan, and the two appeals filed were overturned on the basis of the scientific background for the decision. Thus, the process was successful in regard to products. Most participants felt that all interests were included and that mutual learning about one another's values occurred (McCool and others 2000), so the interest and relationship aspects of success were met. Members of the public differed greatly in the value they placed on research data, scientific presentations, and expert knowledge. Comments ranged from "I didn't learn anything" to "I learned a lot". Thus, the SWC process was partially successful in relationship to education and learning. With regard to the politics and responsibility aspects of success (discussed in the next section), the process was also partially successful. Since participants were interviewed before the SWC plan was approved, the implementation aspect of success has not yet been addressed by BEMRP research.

Is Consensus an Appropriate Goal for Public Involvement?—Consensus can be viewed as a process ("consensus building") or as an outcome ("consensus was reached") (McKinney 1998). Interviews of SWC participants revealed six elements of consensus (McCool and others 2000):

- Agreement that the issue can be resolved through public participation.
- Inclusiveness of all affected interests.
- Common understanding of the problem.
- Equal knowledge among participants.
- General agreement on the proposed action.
- Permission for the agency to act.

Participants agreed that two aspects of consensus were present in the SWC process: Public involvement was definitely appropriate for planning, and the process was inclusive of all interests (McCool and others 2000). However, participants did not all view SWC as successful in reaching agreement on the nature of the problem or the extent to which knowledge, particularly experiential knowledge, was shared among participants. Most participants, but not all, felt they could "live with" the results of the process, even if they were not enthusiastic supporters of the outcome. Thus general (though not unanimous) agreement was present. As evidenced by the appeal on the District Ranger's decision, not all participants gave the agency their permission to act.

Although consensus was not complete in SWC despite "nearly heroic" efforts of the agency to achieve it (McCool and others 2000), the process contributed to consensus building in the Bitterroot community. Several SWC participants commented that the understanding and knowledge of procedures gained in SWC were helpful in subsequent county level comprehensive planning (Guthrie 1997; Pukis 1997). Managers and scientists involved in SWC understand public involvement and mutual learning processes better and have learned the importance of frequent, clear communications about the role and limits of public involvement (McCool and others 2000). Where members of the public have widely differing values in regard to natural resources, a long-term goal of mutual learning about each other, values, and the ecosystem is more appropriate than a short-term goal of consensus (McCool and others 2000).

Alternatives to the “Inform-and-Agree” Model

Key Questions

This section addresses ways to broaden our focus from the agency-centered view, enabling us to consider public involvement in the context of the entire social system and its place within the ecosystem. We synthesize results from research to address the following questions: What is a useful conceptual framework for understanding the social system? How do Bitterroot communities and social systems work? What are the implications of these understandings for public involvement?

BEMRP Activities and Research

Canton-Thompson (1994) described the Bitterroot social system by interviewing opinion leaders in the Bitterroot Valley. She described the community, culture, polity, and perceptions of change that affect the social system. She focused particularly on questions about forest management. A random survey conducted a year later (Menning 1995) supplemented Canton-Thompson’s report with quantitative information about a smaller number of natural resource issues.

Subsequent to the SWC planning process, Richards and McLuskey (1997) studied community and civic groups in the Bitterroot and other areas of the Northern Region to explore how these groups address their missions and might help address land management issues.

What We Have Learned

Five years of experience and research on the human dimension indicate that “plenty of information and plenty of opportunities to learn” do not necessarily produce consensus on goals and practices for wildland management, and that consensus is not necessarily an appropriate goal for public involvement. The main shortcoming of the “inform-and-agree” model is that it is agency-centered: Public involvement efforts originate from goals or products mandated by the agency, so the problems addressed are defined by the agency. BEMRP’s work in the human dimension indicates that a broader view of learning and collaboration is needed. This view depicts the agency functioning *as part of* the social system and the social system functioning *as part of* the ecosystem. Understanding human communities and working with them in the context of their interactions with the environment will more likely result in realistic expectations and successful collaboration over the long term than the “inform-and-agree” model.

What Is a Useful Conceptual Framework for Understanding the Social System?—Agencies operate as part of social systems, which operate as part of ecosystems. A conceptual framework for viewing the social system in this way was not agreed upon when BEMRP began in 1994, but was provided by the Interior Columbia River Basin (ICRB) Assessment in 1996 (Haynes and others 1996) (fig. 4). The ICRB framework describes the basic principles of biophysical systems, which apply to social systems as well. Like biophysical systems, social systems are dynamic, can be viewed as hierarchies with temporal and spatial dimensions (for example, ancestries and future generations, scale from neighborhoods to communities to counties to states, etc.), have limits (where the integrity and survival of the human system is challenged), and are relatively unpredictable (many players and social dynamics across time and space).

Human systems also have order, as the ICRB framework suggests. They can be described by their culture (heritage and identity), community (how people work together to sustain the community or enhance their quality of life), economy (how people sustain themselves financially), and polity (how people govern themselves). A similar view of the social system within the ecosystem is presented in Brunckhorst and Rollings (1999).

How Do Bitterroot Communities and Social Systems Work?—In the Bitterroot Valley, the model of the social system functioning within the ecosystem applies not only figuratively but also literally: Public wildlands, mostly the Bitterroot National Forest, surround the private lands in the valley bottom and comprise approximately 80 percent of the Bitterroot watershed (fig. 5). Residents share a love of the outdoors, but their visions of how they fit within the ecosystem differ (Canton-Thompson 1994). They value public lands for commodities as well as amenities; the balance

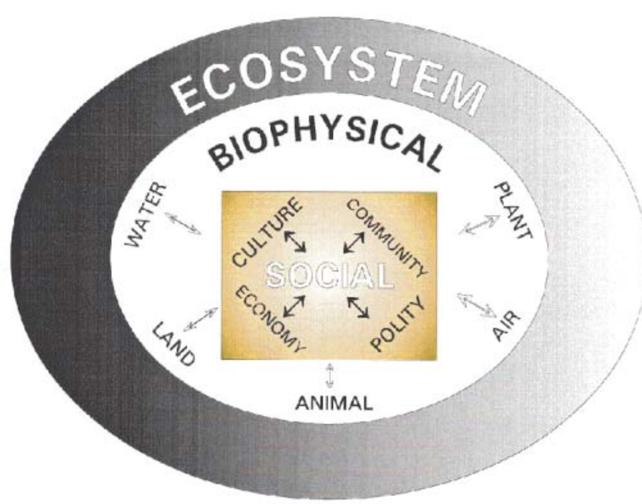


Figure 4—Ecosystems are places where biophysical and social components interact. Energy and resources flow from one component to another. All components vary in space and change over time. Diagram adapted from Haynes and others (1996).

Figure 5—In the Bitterroot Valley, the human community is surrounded by the natural processes and wildlands literally as well as figuratively. Agriculture, timber, recreation, and a growing urban culture shape the social context for ecosystem-based management.

between the two differs among residents and is constantly shifting.

Change due to rapid growth and urbanization is currently very dramatic in the Bitterroot Valley, but change—accompanied by continual tension regarding people's relationship with each other and values about land use—has characterized the human community of the Bitterroot for centuries. Two hundred years ago, the Salish people occupied the Bitterroot, following the cycle of life, harvesting foods when seasonally available. By the late 1800's, the Salish were largely displaced by European American settlers. Salish use and value of the Bitterroot National Forest continues. During the past 100 years, European American residents in the Bitterroot acquired a livelihood from the land through agriculture, timber, and mining. Population growth accelerated in the 1970's and has increased about 40 percent in the last eight years. The people moving in bring a culture that is less tied to natural resource products than that of the early 1900's. In 1992, only 13 percent of the county's basic labor income was related to the timber and agriculture industries. More than half of the county's income was "unearned" (from dividends, interest, and rent) (Canton-Thompson 1994).

Opinion leaders in the Bitterroot Valley described several ways in which their communities address critical issues to maintain or enhance their quality of life (Canton-Thompson 1994): practicing the "golden rule," maintaining economic diversity, being proactive in response to change, and embracing good communications, community spirit, and public involvement. Barriers that confront communities trying to sustain themselves were also mentioned: powerlessness to influence government, lack of infrastructure or institutions within a community, lack of funds, and constant change due to newcomers with new ways of doing things.

What Are the Implications of These Understandings for Public Involvement?—While the Forest Service has required public participation in management since 1960 (Gebhardt 1995), the agency does not mandate a single way to achieve it. The booklet "Strengthening Public Involvement" (U.S. Department of Agriculture, Forest Service 1993) identifies 23 different methods of involving the public and lists 10 potential objectives of public involvement. A public involvement course offered in the Forest Service's Northern Region lists more than 75 ways of working with the public and emphasizes building relationships as a major part of successful communications (Enright 1999). These resources reinforce the findings of Guthrie (1997) that success in public involvement is not limited to achievement of consensus but has many dimensions. While agreement is obviously a positive outcome, other results—new or enhanced understanding of the ecosystems and of participants' values, identification and inclusion of stakeholders, and completion of a high quality plan for sustaining the ecosystem—are equally valid accomplishments. Based on BEMRP research and experience, we suggest four ways in which success in public involvement can be enhanced:

1. Accept tensions within a community as forces that contribute to balanced decisions. If managers understand the dynamic nature of the social system, the infusion of new values that is taking place, and the fact that some facets of the culture and economy can be lost in this time of rapid change, they may form more realistic expectations about public agreement and make more effective choices of public involvement methods. Managers and scientists cannot make tensions among citizens about natural resource issues go away, nor can they freeze the community and ecosystem in time to bring people into agreement. Divergent viewpoints and tensions among community members regarding natural resources form the context for land management. They have been, and can continue to be, a positive force for change (Gebhardt 1995).

Respect among participants is an important aspect of public participation. Some participants in SWC perceived the process as requiring too many meetings and lasting too long; others mentioned lack of civil discourse in public meetings (Pukis 1997). We have learned that consistent, assertive facilitation is essential to provide an environment of respect for all participants and to ensure effective use of their time.

2. Use the infrastructure and polity of the local community to involve the public. Consider land management issues to extend across time, with dialogue and adaptation occurring across many projects or "events." Brunckhorst and Rollings (1999) recommend that agencies craft their governance methods to fit the social and ecological systems they are working with. One size surely does not fit all. Richards and McLuskey (1997) found that community organizations and civic groups work effectively on many community/county issues in Montana and northern Idaho. Groups that have been successful:

- Foster diverse membership and encourage expression and recognition of all opinions.
- Involve all stakeholders early in planning processes.
- Focus on common issues and tangible goals, emphasizing small successes.
- Use a regular facilitator.
- Encourage development of understanding and relationships among participants.
- Encourage individuals to represent themselves rather than interest groups, but recognize political interests.
- Avoid extreme positions and focusing on personalities.
- Use local media and informal networks to communicate.

Community groups, which already have some cohesiveness and experience in collaboration, have the potential to be effective partners in agency planning efforts. “If the goal of public involvement is to incorporate informed citizens into the natural resource decision-making process, then more than one public involvement mechanism needs to be used to provide a more complete opportunity for participation and better representation of the human dimension” (Freimund 1996).

3. Maintain a commitment to obtaining, using, and sharing scientific knowledge. Agency staffs are dynamic by nature, so documentation and archival of knowledge—expert, experiential, and organizational—are essential for effective, long-term management. Monitoring is essential to keep information current and identify trends (U.S. Department of Agriculture, Forest Service 1995). Synthesis of this array of knowledge, archived and new, expert and experiential, must also be transferred to new staff; without archiving and synthesis, the legacy of agency learning will have little significance to a new manager.

A consistent, routine communications program that includes scientists, managers, and the public not only provides knowledge to all participants but also indicates the agency’s commitment to partnership. Newsletters and a Web site may seem impersonal, but they contribute to maintaining relationships between participants. They also provide a way for agency staff to let members of the public know how their comments are being used. People want to know that their participation matters.

4. Develop positive long-term relationships with community groups and members of the public, including newcomers. “It is only through social interactions that any policy such as ecosystem management can become socially acceptable” (Lewis 1993). Positive relationships are essential for learning and collaboration. The public needs opportunities to get to know managers and scientists as people, not just as “experts.” Field trips, catered meals, and potlucks all helped develop relationships among BEMRP partners. When agency staff participate in community events, do volunteer work, and participate in solving community problems not directly related to the agency, they also contribute to developing positive, working relationships with other members of the community (Richards and McLuskey 1997).

Conclusions

Plenty of time and plenty of opportunities to work together, as described in the Introduction, do not necessarily lead to agreement in public involvement processes. Where people’s values differ greatly, information is not likely to produce agreement, especially in short term planning processes, and consensus is not a realistic or appropriate goal. However, lack of complete agreement does not mean lack of success. Increased understanding among partners— understanding of each other, of common and differing values, and of ecosystems—is a strong indicator of success. New and enhanced relationships between managers, scientists, and the public are also evidence of success. For members of the public, agency concerns are only a part of the social system in which they live and work, and agency practices are only one facet of their relationship with wildland ecosystems. No wonder agreement is often out of reach! To develop specific plans and meet short-term goals, managers need to dialogue with a wide variety of community and civic groups using a variety of communications methods, and then address all concerns and values in a synthesis completed by the agency. At the same time, a long-term view is essential, including monitoring and frequent evaluation of public participation efforts. BEMRP research demonstrates the importance of evaluating the effectiveness of public participation so the agency can improve upon processes. Debate over natural resource issues benefits from continuous learning about natural systems and about one another’s experience and values. Mutual learning contributes to growing relationships, and working together may gradually enhance agreement in the community.

Public participation is vital to successful, long-term ecosystem-based management. BEMRP’s experience demonstrates that improving public involvement requires understanding of past and current conditions in the human community, ways in which community members work together to govern themselves, and how people relate to wildland ecosystems.

References

Brunckhorst, David J.; Rollings, Nick M. 1999. Linking ecological and social functions of landscapes: I. Influencing resource governance. Natural Areas Journal. 19(1): 57-64.

Canton-Thompson, Janie. 1994. Social assessment of the Bitterroot Valley, Montana with special emphasis on national forest management. Report prepared by Bitterroot Social Research Institute. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 305 p.

Carlson, Clinton E.; Arno, Stephen; Pfister, Robert D.; Jones, J. Greg; Lyon, L. Jack; Kempf, Madelyn. 1994. Bitterroot ecosystem management/research project master study plan. On file at: Forestry Sciences Laboratory, Missoula, MT. 17 p.

Enright, Diana. 1999. [Personal communication]. July 1. Libby, MT: U.S. Department of Agriculture, Forest Service, Kootenai National Forest.

Freimund, Wayne A. 1996. Chapter 3. The perceived role of tourism in the Bitterroot Valley and implications for forest planning. In: Freimund, Wayne A. The effects of round table public process and technology transfer on the perceptions of the public toward public involvement and ecosystem management. Final report for Research Joint Venture Agreement INT-94930-RJVA. On file at: Forestry Sciences Laboratory, Missoula, MT. 46 p.

Freimund, Wayne A. 1998. The role of computerized communication and the presence of scientists information in the Stevensville West-Central ecosystem analysis process. Technical completion report for Research Joint Venture Agreement INT-96067-RJVA. On file at: Forestry Sciences Laboratory, Missoula, MT. 19 p.

Gebhardt, Christian F. 1995. Public participation in natural resource policy making: a review of the literature. Working paper 95-2. Missoula, MT: Boone and Crockett Wildlife Conservation Program. 59 p.

Guthrie, Kathleen Meyers. 1997. Measures of success in public involvement processes: an investigation of how managers, researchers and members of the public define success. Missoula, MT: University of Montana. 94 p. Thesis.

Guthrie, Kathleen; Freimund, Wayne A. 1996a. Chapter 1. Public involvement with ecosystem management on the Stevensville District of the Bitterroot National Forest. In: Freimund, Wayne A. The effects of round table public process and technology transfer on the perceptions of the public toward public involvement and ecosystem management. Final report for Research Joint Venture Agreement INT-94930-RJVA. On file at: Forestry Sciences Laboratory, Missoula, MT. 46 p.

Guthrie, Kathleen; Freimund, Wayne A. 1996b. Chapter 2. Integrating information sources to improve the integration of public values into ecosystem management and planning. In: Freimund, Wayne A. The effects of round table public process and technology transfer on the perceptions of the public toward public involvement and ecosystem management. Final report for Research Joint Venture Agreement INT-94930-RJVA. On file at: Forestry Sciences Laboratory, Missoula, MT. 46 p.

Haynes, Richard W.; Graham, Russell T.; Quigley, Thomas M. 1996. A Framework for ecosystem management in the Interior Columbia Basin and portions of the Klamath and Great Basins. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 68 p.

Lewis, Bernard J. 1993. Problem analysis: the social dimension of ecosystem management. Unpublished paper. St. Paul, MN: University of Minnesota. 88 p.

Lisowski, M. and Disinger, J.F. 1991. The effect of field-based instruction on student understandings of ecological concepts. The Journal of Environmental Education. 24(1): 19-23.

McCool, Stephen F. 1998. Social science research synthesis report. Review draft of report for Research Joint Venture Agreement RMRS-98504-RJVA. On file at: Forestry Sciences Laboratory, Missoula, MT. 37 p.

McCool, Stephen F.; Guthrie, Kathleen. 1998. Building consensus: legitimate hope or seductive paradox? Technical completion report for Research Joint Venture Agreement INT-96067-RJVA. On file at: Forestry Sciences Laboratory, Missoula, MT. 23 p.

McCool, Stephen F.; Guthrie, Kathleen; Smith, Jane Kapler. 2000. Building consensus: legitimate hope or seductive paradox? Res. Pap. RMRS-RP-25. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 14 p.

McKinney, Matthew. 1998. Resolving public disputes, a handbook on building consensus. Helena, MT: Montana Consensus council. 225 p.

Menning, Nancy Lee. 1995. Opinions about tourism development in the Bitterroot Valley: a survey of residents. Research Report 42. Missoula, MT: The University of Montana, Institute for Tourism and Recreation Research. 30 p.

Pukis, Rick. 1997. Bridges to the future: natural resource management and public involvement in the Bitterroot Ecosystem. Videotape. On file at: Forestry Sciences Laboratory, Missoula, MT. 25 minutes.

Richards, Rebecca Templin; McLuskey, Krista. 1997. An assessment of potential models of public involvement for forest planning on the Bitterroot National Forest. Completion report for Research Joint Venture Agreement INT-96076-RJVA. On file at: Forestry Sciences Laboratory, Missoula, MT. 46 p.

Thomas, Linda; Walsh, James. 2000. The Effectiveness of Structured, hands-on Learning about Wildland Fire. In: Smith, H. Y., ed. The Bitterroot Ecosystem Management Research Project: What we have learned: symposium proceedings; 1999 May 18-20; Missoula, MT. Proc. RMRS-P-XXX. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

U.S. Department of Agriculture, Forest Service. 1993. Strengthening Public Involvement: A National Model for Building Long-Term Relationships with the Public. Washington DC: U.S. Department of Agriculture, Forest Service. 22 p.

U.S. Department of Agriculture, Forest Service. 1995. Navigating into the future, Rensselaerville Roundtable: integrating science and policymaking. Washington: U.S. Government Printing Office: 1995 386-111/00505. 16 p.

Wagner, Thomas G. 1998. Bitterroot Ecosystem Management Research Project: What does it mean on the front line? In: Keegan, C.E., III; Willits, S.; Gorman, T., comps. Proceedings: Forest management into the next century: what will make it work? 19-21 November 1997; Spokane, WA. Madison, WI: Forest Products Society: 39-49.

Webster's New Collegiate Dictionary. 1975. Springfield, MA: G. and C. Merriam Co. 1536 p.

Making “Stuff” Happen Through Public Participation and Consensus Building

Stephen F. McCool

Abstract—The increasing emphasis on public participation in ecosystem-based planning suggests an enlarging need to determine what makes public participation successful and what criteria are useful in identifying when a consensus has been reached. These two questions were investigated in research involving two small planning areas on the Bitterroot National Forest. It was determined that successful public participation was multidimensional and involved writing a plan, plan implementation, social acceptability, learning, interest representation, responsibility, and relationships. Six conditions for consensus were found: agreement on the problem; problem definition is shared; inclusive of belief systems affected by the decision; extent to which participants can live with the decision; equal access to information and decision-makers; and extent to which agency is given permission to act.

With the expanding recognition that resource management decisions must recognize both biophysical and social processes at larger spatial scales and longer time frames, resource managers have become particularly challenged at uncovering an information base to support decisions. Increasingly, management has relied on an ecosystem-based management paradigm to address the consequences of decisions, but in so doing has become even more reliant on science to find the answers to questions about how demands for goods and services can be met. This expert driven, science based model of management, while qualitatively different from the recent past, also requires decision making processes that are more inclusive of the diversity of values, range of interests, and assorted perspectives that are affected by ecosystem-based management. The expert driven model of planning exemplified in ecosystem-based management served well when the dominant products of natural resources management were commodities, when decisions were made at the stand level, and when there was an apparent public consensus about the goals of resource management. However, as the goods and services ecosystems are expected to produce have broadened and extended beyond commodities there has been increasing conflict over what should be produced.

These conflicting goals as well as scientific disagreement over cause-effect relationships result in messy situations, as opposed to tame problems where there is agreement on goals and scientists can point the way to cause-effect relationships (Ackoff 1974). These messes are also characterized by an interacting set of sub problems that generally cannot be solved in isolation of each other. Identifying the presence of linked sub problems often occurs only when those affected by proposed plans are directly involved in their development. That these types of problems occur in natural resources planning and management has long been recognized (Allen and Gould 1986).

In messy situations, understanding what makes for successful public participation can be problematic. While implementation or modification of a proposed project or decision may be one such measure, the need to learn and understand is fundamental. While a few recent studies have examined measures of successful public participation (e.g., Shindler and Neburka 1997; Wondelluck and Yaffee 1994; Moore 1994), none have specifically linked such measures to messy situations. In such situations, meanings of success have important implications for the organization of public discourse, design of meetings, and development of planning strategies. Narrow definitions, oriented toward informing the public of proposed actions, may result in incomplete specification of the problem and development of opposition.

Typically, messy situations are accompanied by intense conflict; one-way flows of information from planner to the public may create more in the way of disagreement about proposed actions than agreement among those publics affected. Action in society requires a variety of actors working in concert, and thus, they must agree on not only a desired future, but the means to get there. This condition is commonly termed a “consensus,” but the conditions that lead to consensus are problematic in many situations.

The need to understand the meaning of successful public participation and the conditions for consensus drove this research.

Methods

Two relatively small, adjacent and procedurally linked planning projects in the Bitterroot Valley of western Montana served as the setting for examining the meaning of successful public participation. Both projects were conducted by the Stevensville District of the Bitterroot National Forest and designed to address ecosystem-based management issues at a landscape scale. Each project (the Stevensville Southwest and Stevensville West Central) was conducted sequentially, involved numerous meetings (about 40) with members of the public, and was directed toward developing management actions for a variety of forest uses—including timber, grazing, watershed, recreational, and wildlife values. The projects were conducted over the period 1992 to 1996. Currently, formal environmental analyses on both have been approved, following unsuccessful administrative appeals by various

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Stephen F. McCool is a Professor, School of Forestry, University of Montana, Missoula, MT 59812.

interests. The public participation process involved a variety of formats, including typical agency informational meetings, small group processes, field trips, and presentations from participating scientists.

Both projects were similar in size (about 40,000 acres) and scope of issues. Each was based on the concept of ecosystem-based management. The Stevensville West Central Unit had a significantly higher level of public involvement in an attempt to create a consensus about management direction. In addition, a focused scientific effort was initiated by the (then) Forest Service Intermountain Research Station to create a larger information base upon which to make decisions. Scientists from various programs and departments from The University of Montana also participated. An important feature of the scientific participation involved presentations by scientists to both federal managers and members of the public to increase awareness of important ecosystem processes and functions in the planning area. In this study, all scientific and managerial participants in the project were interviewed to identify meanings of success. About half the public participants were sampled. Public participants (which included a typically wide range of beliefs and political positions about natural resources management) interviewed were sampled to achieve representativeness of perspectives on the project. In addition, some participants were unavailable for an interview; only one declined. Interviews were conducted in the summer and fall of 1996, with six additional follow-up interviews initiated in the summer of 1997.

Forty individuals were interviewed. All interviews were conducted on a confidential basis. Interviewees were asked about a number of process characteristics, including their perceptions of the public participation component of the planning effort. Each participant was asked if the participation component was successful, and then followed up with questions about why (either it was or was not successful). Following this discussion, each was also asked whether a consensus existed and what conditions were needed to reach it. Each interview was tape recorded with the permission of the individual and was later transcribed. Transcribed interviews were subject to a content analysis; key concepts were identified and marked using Ethnograph statistical software. Both Guthrie (1997) and McCool and Guthrie (1998) provide additional detail on methods and results.

Results

Interviewees identified a number of dimensions of successful public participation. Obviously, the ability to change the future to a more desirable one through writing and implementing a plan is an important dimension. As one respondent stated, “stuff's gotta happen.” However, this narrow definition of success was not widely shared by respondents in this study. Study informants identified other dimensions critical to a successful process. These dimensions include identifying the social acceptability of plan alternatives. Since public resources must be organized to implement any plan in the public domain, social acceptability is critical as noted by several interviewees.

These product-oriented measures of success are particularly important in tame problem situations, but for messy problems—where there is disagreement and uncertainty—are rather limited. Given the need for greater amounts of inclusiveness and legitimate consideration of a wider range of values, these other dimensions appear essential for successful public participation in messy situations.

First, respondents emphasized learning-oriented dimensions of success. In this sense, learning was most often discussed as a two-way or interactive concept. In this respect, learning is differentiated from education—which a number of scientists in our study identified as an important dimension. The learning that occurred appeared to concern not only the topic—ecosystem-based management (as applied to the specific areas involved here)—but also the process of communicating with each other, and understanding legal and policy processes that guide planning and management.

Interviewees in this study also identified responsibility (in the sense of ownership) as another dimension of success in two ways: first, seeing their input reflected in the document or decision, and second, feeling like their issues and concerns were accepted and considered. Responsibility for an area/plan differs from acceptability in the sense that a plan produced by an agency distant from the public may be satisfactory (and acceptable), but the public may have no feeling that they helped write the plan. Responsibility may be important in securing the resources necessary for implementation. This dimension was particularly important for the public.

Still another dimension of successful participation identified by the informants in this study deals with relationships not only between managers and members of public but also among the public and between scientists and the public. Relationship building goes to the heart of the trust issue, which has plagued many federal agencies over the last decade or so.

In many respects, planning represents a redistribution of power, away from entrenched interests to those who have formerly been relatively powerless; in this sense, a broad representation of various interests in the planning process is essential, as recognized by many interviewees in this study. In part, interest representation includes not only a variety of stakeholders but also access to the planning process.

Interviewees identified six conditions necessary for achieving consensus on a proposed course of action. An underlying element of the consensus concept is the notion of agreement not only on a resolution to the problem, but also on the definition of the problem itself. Thus, the extent to which there is a shared definition of the problem is an important condition necessary to achieving consensus. As Bardwell (1991) notes, too much problem solving activity is directed toward solving the wrong problem or solving a solution. Shared definitions help in directing the course of discussion.

In order to create consensus, there must be agreement that the problem can be resolved through public participation processes, the second condition identified by respondents. This condition is critical because some, particularly scientists and managers, may hold beliefs that only expert or scientific knowledge is necessary for the planning process. Ecosystem-based management has largely been defined as a scientific process, with the public more or less on the outside looking in and playing a role only marginally different from the formal public participation requirements of National Environmental Policy Act (NEPA). Informants in this study, however, felt that public participation was an essential, if not sole, component of the planning process.

Public participation processes that attempt to build consensus must be inclusive of the belief systems that are affected by policy, the third condition. There was recognition among nearly all interviewees that a consensus building process must be inclusive of various values and interests, and at least some participants recognized a good faith effort on the part of the agency to be inclusive. This is an important finding because perceptions of process go to the heart of concerns about trust and legitimacy. A process that is viewed as exclusive or biased at the beginning will have little social validity at its closing, if it makes it that far. The extent to which the process is viewed as inclusive is positive and conducive to building consensus and trust with the agency.

The fourth condition deals with the heart of consensus, the extent to which participants can live with results. The nature of agreements made in a public participation process is the basis of consensus, and, as noted earlier, there is a lack of attention to this fundamental question in the literature. To some, consensus may mean unanimous opinion, to others a general agreement, and to still other participants, a level of agreement where some participants may be happy and others may go along grudgingly. The variety of definitions of agreement or consensus can be a significant stumbling block to knowing when “agreement” has been reached and when to move on to other issues. However, in this case, most respondents independently identified a “can live with it” definition.

People must engage each other on equal footing in order for authentic interaction to occur. In the Stevensville projects, Forest Service planners and scientists attempted to communicate the technical data and modeling needed to better understand the ecosystem. This was done through numerous public meetings and field trips. The effect of this attempt may not have been to resolve a particular planning problem as much as to increase awareness of ecological processes. Communicating scientific knowledge to the public and agency planners was a fundamental objective of the planning effort. The comments reported here suggest that achieving this goal was inhibited by value differences, particularly between the agency and its publics. Which facts people agree to and which they do not hinders problem definition; the data presented here suggest some confusion about the problem definition. A variety of other factors, including fundamental belief systems about the management of public lands and trust levels, intervene in developing a consensus. The data also suggest that scientists need to consider the varying cognitive capacities of public members when communicating the complex ecological principles of ecosystem-based management.

The sixth condition identified was the extent to which an agency was given “permission” to act. The idea of informed consent has been in the literature for many years. If the agency does not have the confidence of its public to implement actions, it has lost its legitimacy as agent of public policy. Permission to act occurs at a general level and does not mean unanimous acceptance. In the complex and contentious situations confronting natural resources, such agreement would be rare and unrealistic to expect. One manager observed that not all people will agree with proposed actions and that it is important for planners to recognize this. While one manager was rather fatalistic about the project-achieving consensus (“We will NEVER make everyone happy nor is this possible”), a scientist felt “that it’s better than no process whatsoever” even though this scientist felt that a consensus had not been achieved.

Conclusions

This research certainly suggests that involving the public in natural resource planning, while ultimately worthwhile, is anything but easy. The research points to the need to build such processes on clearly established goals (e.g., learning) and to have clarity into the meanings of important terminology. In the case studies used in the research reported here, the public participation process was extensive, and while not every participant could live with all the results, it did seem to result in a set of outcomes more representative and acceptable than a traditional NEPA process would have led to.

The process of building consensus is confronted by considerable obstacles, including the lack of skill in leading public participation programs (suggestions for overcoming these are made by Shindler and Neburka 1997), and a number of institutional barriers. Major institutional barriers are the perceptions about the requirements of the Federal Advisory Committee Act (FACA), passed in 1972. This legislation prohibits advisory committees to the federal government that contain nonfederal employees without a specific charter from the General Services Administration. Because of several recent court cases involving FACA and natural resource planning, federal land management agencies have been reluctant to engage in intensive, consensus building public participation programs. The court interpretations of FACA have varied considerably, leaving many planners in a dilemma—wanting to engage the public in more deliberative processes, but also wanting to avoid legal entanglements that may lead to invalidation of any resulting plan or decision.

The methodology used in this study was distinctly qualitative in nature. The objective was to map out the various dimensions of success and consensus, as viewed by participants. Future research would involve gaining a better understanding of the quantitative importance and external validity of these dimensions in other natural resource planning situations. Other research questions might investigate the strategies various groups employ when they perceive their positions are minority or majority ones, when belief systems of participants simply do not allow some alternatives to be considered, or when identifying effective ways for participants coming to similar definitions of the problem.

References

Ackoff, R.L. 1974. Redesigning the future: A systems approach to societal problems. New York, NY: John Wiley and Sons. 260 p.

Allen, G.M.; Gould, E.M., Jr. 1986. Complexity, wickedness and public forests. Journal of Forestry. 84(4): 20-24.

Bardwell, L. 1991. Problem framing: A perspective on environmental problem-solving. Environmental Management. 15(5): 603-612.

Guthrie, K. 1997. Measures of success in public involvement processes: An investigation of how managers, researchers and members of the public define success. Missoula, MT: School of Forestry, The University of Montana. 98 p. Thesis.

McCool, Stephen F.; Guthrie, Kathleen; Smith, Jane Kapler. 2000. Building consensus: legitimate hope or seductive paradox? Res. Pap. RMRS-RP-25. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 14 p.

Moore, S.A. 1994. Interaction processes and the resolution of environmental disputes: Case studies from public land planning in the United States and Australia, College of Forestry, University of Washington, Seattle, WA.

Shindler, B.; Neburka, J. 1997. Public participation in forest planning—8 attributes of success. Journal of Forestry. 95(1): 17-19.

Wondolleck, J.M.; Yaffee, S.L. 1994. Building bridges across agency boundaries: In search of excellence in the United States Forest Service. (Ann Arbor, MI: School of Natural Resource and Environment, The University of Michigan). A research report to the U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Behavioral and Cognitive Evaluation of *FireWorks* Education Trunk

Linda R. Thomas
James A. Walsh
Jane Kapler Smith

Abstract—This study assessed the effectiveness of *FireWorks*, an educational trunk about wildland fire, in increasing student understanding, enabling students to apply classroom learning in a field setting, and improving the learning environment. Students who were in classrooms using the *FireWorks* educational trunk demonstrated more knowledge in both classroom and field-based tests than did students in comparison groups. Students using *FireWorks* were more interested and engaged in learning than students in comparison classrooms. *FireWorks* students rated their classrooms as being more orderly and better organized, and rated their teachers as more innovative, creative, and interested in student input than did students in comparison groups. Teachers of *FireWorks* were less likely to be interrupted to reprimand students than were teachers of comparison classrooms.

Field-based environmental education is effective in fostering student understanding of ecological concepts (Lisowski and Disinger 1991), but financial and logistical constraints limit field instruction for most schools. Environmental education in the classroom also encounters barriers; among them are shortage of preparation and teaching time, lack of specific instructional materials, and teacher concerns about their own expertise (Ham and Sewing 1987). To address barriers to environmental education in the classroom, educators have developed traveling boxes, also called "educational trunks." Filled with hands-on materials and supplied with curricula for specific grade levels, educational trunks provide teachers with materials for experiential learning and structured lessons about the environment. The low cost associated with borrowing the educational trunk and the training that teachers receive help to address teachers' concerns about costs, preparation time, and their own qualifications.

A study examining the use of educational trunks for environmental education indicates that trunks are effective in teaching environmental concepts and that their use is increasing in many parts of the United States (Roy and others 1997). However, the same research suggests that the trunks' effectiveness has not been thoroughly investigated. Can students transfer what they learn from an educational trunk in the classroom to a field environment? How does the use of educational trunks affect the classroom-learning environment?

This study evaluated the effectiveness of *FireWorks*, an educational trunk that provides materials and curricula for learning about wildland fire. In 1995, the U.S. Department of Interior and U.S. Department of Agriculture recommended that "…a clear message about the important role of fire as a natural process" and an "understanding of policies concerning wildland fire and the urban interface" be communicated to the general public (U.S. Department of Interior and U.S. Department of Agriculture 1995). In response, *FireWorks* was prepared in 1997 and 1998 by staff at the Fire Sciences Laboratory, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station (Smith and McMurray 2000).

This study assessed student understanding of the following six subject matter areas covered in the *FireWorks* educational trunk:

1. The physical science of combustion, especially in wildland fuels.
2. Community ecology, especially the concept that a forest has many kinds of plants and animals, which change over time and influence one another.
3. The role of fire as an important natural process in many forest ecosystems.
4. Ways in which native plants and animals survive fire and/or reproduce after fire.
5. People's influences on fire-dependent wildlands in the areas where they live.
6. The concept that people respond in different ways to fire-related questions.

The evaluation included assessment of skills acquired as part of the hands-on learning in each lesson: observing; describing observations; stating hypotheses; explaining reasoning; classifying information; identifying and expressing responses to fire-related questions; working in teams to solve problems; measuring, counting, and computing; and critical listening and reasoning. Learning environment was also assessed.

The study investigated three hypotheses: (1) that seventh grade students who used *FireWorks* would show a greater gain in knowledge from pre- to post-test than seventh graders who did not use *FireWorks*, (2) that seventh graders in *FireWorks* classes would demonstrate more knowledge in a field-based test than students who were not exposed to *FireWorks*, and (3) that seventh graders using *FireWorks* would demonstrate more interest and engagement in the classroom than seventh graders who did not use *FireWorks*.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Linda R. Thomas is a Doctoral Student and a Research Associate, and James A. Walsh is a Professor Emeritus, Department of Psychology, University of Montana, Missoula, MT 59812. Jane Kapler Smith is an Ecologist, Fire Effects Unit, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 8089, Missoula, MT 59807.

Methods

Participants

Three school districts in western Montana volunteered to participate in the *FireWorks* evaluation: one an urban district, one semi urban, and one rural. Seven classrooms from three schools in the urban district participated in either the *FireWorks* (n = 5) or the non-*FireWorks* comparison groups (n = 2). Both the rural school district and the semi urban district each had one school with three classrooms that received the *FireWorks* curriculum (n = 6). No comparison groups came from either the rural or semi-urban district. A total of 313 seventh grade students participated in the study (treatment group n = 261; comparison group n = 52).

Assessment Procedures

Two approaches were used to evaluate the effectiveness of *FireWorks* in increasing student understanding: cognitively oriented pre- and post-tests, and a behavioral assessment in a field setting. Students' perceptions about the classroom environment were surveyed. Teachers, students, and the interactions between them in the classroom were also observed.

Pre- and Post-Test Cognitive Measure—Two 13-item, multiple-choice tests were constructed from sample questions submitted by each of the volunteer teachers who would be teaching the *FireWorks* curriculum. The two forms of the test (A and B) addressed the same learning domain. All participating classrooms used Form A as the pretest and Form B as the post-test.

Field Test—Field tests were conducted at six "information stations." Each station was staffed by a "stationmaster" who gave each student a single task to perform, evaluated the student's answer, and punched the student's response card to indicate whether the answer was correct or not. Tasks for the field test were based on the lessons in the *FireWorks* curriculum.

Classroom Environment Scale (CES)—Students in all *FireWorks* and comparison classes completed the CES, a 90-question survey with true or false response choices that make up nine subscales. The CES purports to measure conditions in which students can learn (Felner, Ginter, and Primavera 1982, as cited in Moos and Trickett 1995). It also systematically assesses relationships among students.

Classroom Observations—Time sampling was conducted during *FireWorks* instruction in treatment classrooms and during the same time period in comparison classrooms.

Results

Students using *FireWorks* demonstrated a significant gain in knowledge about wildland fire from pre- to post-test, significantly different from the change in knowledge by comparison students [$F(1,1) = 14.54$, $p < .0005$] even though many had studied fire ecology the previous year. Students using *FireWorks* performed significantly better in a field demonstration of skills than did students who did not receive the *FireWorks* instruction [$F(1, 239) = 13.65$, $p < 0.0005$].

FireWorks students perceived their classrooms as more positive places for learning than did students in comparison classes. According to the Classroom Environmental Scale, *FireWorks* students perceived themselves as more attentive and interested in class activities than did comparison students [$F(4,211) = 14.95$, $p < 0.0005$]. Students viewed *FireWorks* teachers as more trusting and interested in student ideas [$F(4,211) = 10.76$, $p < 0.0005$], more likely to emphasize completion of activities [$F(4,211) = 4.32$, $p = 0.002$], more innovative and more likely to encourage creative thinking than teachers not using *FireWorks* [$F(12,278) = 11.58$, $p < 0.0005$]. Students in *FireWorks* classrooms were more likely than students in comparison groups to report competition with other students for grades and teacher recognition [$F(4,211) = 4.10$, $p = 0.003$]. *FireWorks* students rated their classrooms as being more orderly and organized than did students in comparison groups [$F(4,211) = 10.38$, $p = 0.0005$].

Classroom observations indicated that teachers in *FireWorks* classrooms were significantly less likely to interrupt instruction in order to reprimand students for infractions of rules than were teachers of comparison classrooms [$F(1, 14) = 4.96$, $p = 0.043$].

Discussion

This study demonstrated that *FireWorks*, a curriculum about wildland fire available as a traveling educational trunk, was effective in increasing understanding of wildland fire behavior and fire ecology by seventh grade students.

Educators often seek to teach about ecology and outdoor skills in their classrooms, either to maximize the value of a subsequent field trip or to take the place of field trips, which may be expensive or difficult to schedule. This study suggests that educational trunks can be effective for teaching field related knowledge and skills in the classroom. After using *FireWorks*, the seventh graders in this study were able to discuss fire behavior and fire ecology in the field; they assessed potential fire spread, identified tree species, and critiqued the safety of homes in forested areas.

Classroom observations and student responses to the Classroom Environment Scale indicated that a structured, hands-on learning program such as *FireWorks* can facilitate a better learning environment, more positive perceptions of the teacher, and greater student involvement than does routine instruction. The positive influences of a trunk-based educational program on understanding and the learning environment are probably not limited to seventh graders. Research assessing the influence of structured, hands-on learning on perceptions of adult learners would be helpful for educators and agency staff who plan and implement educational programs about ecology.

The *FireWorks* educational trunk addresses several of the barriers to environmental education reported by Ham and Sewing (1987): *FireWorks* minimizes teacher preparation time by providing background, lesson plans, and student handouts ready to use. It eliminates costly expenditures by providing all specialized supplies and equipment for experiments. It provides specific instructional materials and sample exams. Finally, it provides resources for increased teacher competence in education about wildland fire.

Even though students using *FireWorks* showed evidence of increased knowledge about fire ecology, this study did not investigate whether they actually used any of this information. Research is currently underway to determine how much knowledge gained from *FireWorks* was retained for one year. Informal assessment is being conducted to determine whether knowledge gains resulting from use of *FireWorks* influence a student's future behavior regarding wildland fire. This information and formal assessment of long term effects on student attitudes and behavior would be useful to those who examine the cost-effectiveness of educational programs.

References

Ham, S. H.; Sewing, D. R. 1987. Barriers to environmental education. Journal of Environmental Education. 19(2): 17-24.

Lisowski, M.; Disinger, J. F. 1991. The effect of field-based instruction on student understandings of ecological concepts. Journal of Environmental Education. 24(1): 19-23.

Moos, R.; Trickett, E. 1995. Classroom Environment Scale: Development, Applications and Research, Third Edition. Palo Alto, CA: Consulting Psychologists Press, Inc.

Roy, M.; Petty, R.; Durgin, R. 1997. Traveling boxes: A new tool for environmental education. Journal of Environmental Education. 28(4): 9-17.

Smith, Jane Kapler; McMurray, Nancy E. 2000. *FireWorks* Educational Trunk. In: Smith, H. Y., ed. The Bitterroot Ecosystem Management Research Project: What we have learned: Symposium proceedings; 1999 May 18-20; Missoula, MT. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

U.S. Department of Interior and U.S. Department of Agriculture. 1995. Federal wildland fire management policy and program review, final report (December 18, 1995). Boise, ID: National Interagency Fire Center, Bureau of Land Management, Office of Fire and Aviation. 45 p.

Synergy Between Ecological Needs and Economic Aspects of Ecosystem Restoration

Charles E. Keegan, III
Carl E. Fiedler

Abstract—The implementation of properly designed treatments to restore and sustain desired forest conditions in the Inland Northwest, besides moving forest stands more rapidly to an ecologically desirable and sustainable condition, can generate positive revenues from the timber to be removed. These treatments also have potential to increase the number of relatively high paying jobs, especially in rural areas where per capita incomes are nearly 30 percent below those of urban areas. In contrast the much-proposed thin-from-below prescription commonly does not fully accomplish ecological goals and often requires a subsidy of several hundred dollars per acre to implement.

Fire exclusion and selective harvest of the financially valuable seral species have resulted in ecologically unsustainable conditions on millions of acres of forestlands in the western United States. Treatments aimed at restoring these stands to more sustainable conditions have generally been viewed as requiring substantial subsidies; however, our work indicates that projects designed to restore and sustain desired forest conditions in the Inland Northwest often produce timber products with substantial positive value to underwrite treatment costs. Capitalizing on this potential value requires that prescriptions be designed to fully address ecological problems and that they be focused on areas most in need of treatment.

We illustrate this by examining a common stand condition in the ponderosa pine (*Pinus ponderosa*) forest type, which in one form or another covers tens of millions of acres in the Interior West. Our analysis was conducted on stand inventory data from the Bitterroot National Forest in western Montana, as part of the Bitterroot Ecosystem Management Research Project (BEMRP).

The example we use in this paper is a moderately high-density (120 ft^2 basal area/acre) ponderosa pine/fir stand condition, with a dense understory primarily comprised of Douglas-fir (*Pseudotsuga menziesii*). Ecological problems are manifested by high fire hazard, with pockets of mortality due to the mountain pine beetle (*Dendroctonus ponderosae*), and successional transition from early seral to late seral species composition.

We examine two prescriptions for restoring sustainable, ponderosa pine-dominated conditions. The first prescription is a comprehensive treatment approach aimed at addressing ecological problems, high stand density, excessive numbers of sapling- and pole-sized trees, and species composition skewed toward Douglas-fir.

The second prescription involves the often-recommended thin-from-below approach, designed primarily to reduce fire hazard by removing the sapling/pole understory layer. These understory trees can serve as "ladder" fuels, allowing surface fires to torch into the overstory.

Methods

We analyzed U.S. Forest Service records from hundreds of stands that were historically dominated by ponderosa pine and evaluated the potential of timber products to underwrite the costs of restoration treatments. Stands that were selected to be included in the evaluation had to meet the following criteria:

1. Basal area density $\geq$100 ft^2/ac.
2. Significant ladder fuel component.

We then developed a comprehensive restoration treatment prescription for the average (composite) stand condition in the mature pine/fir type that met the previously defined criteria. This "consensus" prescription was developed in consultation with silviculturists and ecologists from various agencies.

The comprehensive prescription includes the following silvicultural treatments:

1. Low thinning in which nearly all of the trees <9 inches in diameter are cut.
2. Modified selection cutting to reduce density and promote regeneration of ponderosa pine.
3. Improvement cutting to remove most Douglas-fir/true firs (*Abies* spp.) as well as low-quality trees of all species not reserved for other purposes.

The target stand density following these treatments is 50 ft^2/acre.

The thin-from-below prescription evaluated for the mature pine/fir condition is aimed at cutting most (or nearly all) of the trees $\leq$9 inches in diameter. Trees <5 inches are cut and slashed, while trees from 5 to 9 inches in diameter are removed and available for products.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Charles E. Keegan, III, is the Director of , Forest Industry and Manufacturing Research, Bureau of Business and Economic Research, The University of Montana, Missoula, MT 59812. Carl E. Fiedler is an Associate Research Professor, School of Forestry, The University of Montana, Missoula, MT 59812.

Using diameter and species, we identified the potential timber products available from the trees we wanted to eliminate in the treatments. We then compared their potential value as timber products delivered to mills, less harvest and haul costs.

We developed harvest costs using an expert system approach. We presented a detailed description of stand conditions, along with descriptions of the two treatment prescriptions, to logging companies and asked them to bid on the harvest operations. The cost of logging was estimated for typical systems used on flat to moderate terrain (slopes under 35 percent) and for steeper ground requiring cable systems.

Results

The comprehensive restoration treatment is clearly superior in terms of ecological effects, the financial aspects of carrying out the treatment, and its potential to positively impact employment and wages in rural communities in the Inland Northwest. The comprehensive treatment prescription is designed to induce pine regeneration, develop and sustain old growth pine, reduce composition of late-successional species, and manipulate structure to reduce fire hazard. Thinning-from-below, a widely proposed restoration treatment for pine forests, does not address the full range of problems that threaten their sustainability. Rather, it only provides short- to mid-term reduction of fire hazard and a modest increase in vigor of leave trees.

Besides moving the stand more rapidly to an ecologically desirable and sustainable condition, the comprehensive restoration approach generates positive revenues from timber products ranging from $300 to over $1000/acre, depending on stand conditions, local industry infrastructure, and market conditions. Our analysis indicates that the thin-from-below prescription not only does not fully accomplish key ecological goals, but also commonly requires a subsidy of hundreds of dollars per acre.

Broad scale application of comprehensive restoration treatments should sustain and even boost forest industry and agency employment. Both of these sectors are among the highest paying components of the economy in much of the rural West. Harvesting timber with commercial value, in addition to underwriting treatment costs, supports employment in processing of the removed material. The proposed treatments themselves are labor intensive—even those using only prescribed burning require fire specialists and large fire control crews. Treatments that employ silvicultural cutting to reduce hazard are also more labor-intensive than traditional harvesting because they are designed to produce a desired forest condition—not just remove timber at a low cost.

Discussion and Conclusion

We have looked at a number of forest types and potential prescriptions and found the timber products produced in ecosystem restoration treatments often have a substantial positive value that can be used to underwrite treatment costs. Further, we have found that there is often a synergy between economic opportunity and ecosystem restoration. That is, implementing comprehensive restoration treatments in the stands most in need of treatment often results in increased timber product values and less need to subsidize the restoration activities.

The implementation of treatments designed to restore and sustain desired forest conditions has large potential to increase employment, especially in rural areas where per capita incomes are nearly 30 percent below those of urban areas. This is particularly true in Montana, which ranks 50th in average wages per worker.

This paper is based on the publications listed in the References section, which were produced at least in part through funding provided under the Bitterroot Ecosystem Management Research Project.

References

Arno, S.F.; Harrington, M.G.; Fiedler, C.E.; Carlson, C.E. 1996. Using Silviculture and Prescribed Fire to Reduce Fire Hazard and Improve Health in Ponderosa Pine Forests. In: Proceedings, 17th Annual Forest Vegetation Management Conference, Redding, CA: 114-118.

Arno, S.F.; Harrington, M.G.; Fiedler, C.E.; Carlson, C.E. 1995. Restoring Fire-Dependent Ponderosa Pine Forests in Western Montana. Restoration and Management Notes. 13: 32-36.

Barbour, R.J.; Keegan, C.E.; Van Hooser, D.D. 1998. Changing Timber Quality in the Western United States. In: Forest management into the next century: what will make it work? Conference Proceedings. 1997 Nov. 19-21; Spokane, WA. Madison, WI: Forest Products Society: 126-135.

Blatner, K.A.; Keegan, C.E.; O'Laughlin, J.; Adams, D.L. 1994. Forest Health Management Policy: Case Study in Southwestern Idaho. Journal of Sustainable Forestry. 2: 317-337.

Blatner, K.A.; Keegan, C.E.; Wichman, D.P. 1998. Roundwood Pulpwood Markets and Ecosystem Restoration Prescriptions. In: Forest management into the next century: what will make it work? Conference Proceedings. 1997 Nov. 19-21; Spokane, WA. Madison, WI: Forest Products Society: 121-125.

Fiedler, C.E. 1996. Silvicultural Applications: Restoring Ecological Structure and Process in Ponderosa Pine Forests. In: Hardy, C.C.; Arno, S.F., eds. The Use of Fire in Forest Restoration. Gen. Tech. Rep. INT-GTR-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 39-40.

Fiedler, C.E.; Arno, S.F.; Harrington, M.G. 1996. Flexible Silvicultural and Prescribed Burning Approaches for Improving Health of Ponderosa Pine Forests. In: Covington, W.; Wagner, P.K., tech. coords. Conference on adaptive ecosystem restoration and management: restoration of Cordilleran conifer landscapes of North America; 1996 June 6-8; Flagstaff, AZ. Gen. Tech. Rep. RM-GTR-278. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 69-74.

Fiedler, C.E.; Arno, S.F.; Harrington, M.G. 1998. Reintroducing Fire in Ponderosa Pine-Fir Forests After a Century of Fire Exclusion. In: Pruden, T.L.; Brennan, L.A., eds. Fire in Ecosystem Management: Shifting the Paradigm from Suppression to Prescription. Proceedings, Tall Timbers Fire Ecology Conference. Number 20. Tallahassee, FL: Tall Timbers Research Station: 245-249.

Fiedler, C.E.; Keegan, C.E.; Arno, S.F. 1997. Utilization As a Component of Restoring Ecological Processes in Ponderosa Pine Forests. In: Role of wood production in ecosystem management: proceedings of the Sustainable Forestry Working Group at the IUFRO All Division 5 Conference; 1997 July; Pullman, WA. Gen. Tech. Rep. FPL-GTR-100. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory: 24-29.

Fiedler, C.E.; Keegan, C.E.; Arno, S.F. 1998. Some Thoughts on the Ecological and Economic Implications of Ecosystem Restoration. In: Forest management into the next century: what will make it work? Conference Proceedings. 1997 Nov. 19-21; Spokane, WA. Madison, WI: Forest Products Society: 159-163.

Fiedler, C.E.; Keegan, C.E.; Arno, S.F.; Wichman, D.P. 1999. Product and Economic Implications of Ecosystem Restoration. Forest Products Journal. 49: 19-23.

Steele, B.M.; Fiedler, C.E. 1996. Kalman Filter Analysis of Growth-Climate Relationships in Old-Growth Ponderosa Pine/Douglas-Fir Stands. Radiocarbon. 38: 303-314.

Wagner, F.G.; Keegan, C.E.; Fight, R.D; Willits, S.A. 1998. Potential for Small-Diameter Sawtimber Utilization by the Current Sawmill Industry in Western North America. Forest Products Journal. 48: 30-34.

Social Science and the Bitterroot National Forest: A Synthesis

Stephen F. McCool
James Burchfield
Wayne Freimund

Abstract—The objective of this research was to synthesize a number of studies focusing on human dimensions of public land management in the Bitterroot National Forest. While 35-40 such studies have been conducted, their cumulative knowledge is limited by use of a variety of approaches, scales and frameworks. Four themes emerged from the synthesis: public attitudes toward management of national forest lands; the relationship between the Forest Service and local residents; recreation and wilderness use; and the linkages between the Bitterroot National Forest and local economic development.

The Bitterroot National Forest has been at the center of resource management conflicts for over a quarter century. Timber harvesting, aesthetic resource management, wilderness fire management, and endangered species restoration have all seemed to find their way to the Forest. A rapidly growing, and socially polarized, setting has often served as the context for this continuing series of conflicts, which do not occur in isolation of other issues confronting the local population.

While a number of researchers have sought to understand various dimensions of this context, as well as the social and political basis for them, that research has never been synthesized. The research has encompassed a variety of project types and methodologies, including recreation and aesthetic preferences of wilderness visitors, attitudes toward resource management activities and tourism, dimensions of public participation in resource decisions, and economic development strategies.

This project had three major objectives:

1. Find meaning, in terms of general conclusions, not restate data, in the results of this research;
2. Provide an interpretive assessment, stated in terms of general propositions useful for ecosystem-based management, of social science research in, about and for the Bitterroot National Forest; and
3. Identify gaps in knowledge and potential research questions that could guide future social science research so that it is not only more useful, but better integrates with other sciences.

A final report (McCool and others 1999) has been produced.

The Social Context for Research in the Bitterroot National Forest

Several major contextualizing factors influence how the research was conducted and its meaning within the context of ecosystem-based management processes on the Bitterroot National Forest (Bitterroot Forest). These factors include:

- The geographic context for the Bitterroot Forest places it within a region of concentrated amenities juxtaposed to significant commodity resources.
- The mountains surrounding the valley serve as an attractant to new residents because of their scenic beauty and proximity for outdoor recreational experiences.
- Dramatic increases in human population place strains on the urban-wildland interface.
- The natural resources management policy environment is characterized by lack of agreement over goals and methods.
- Federal funding for management of the Bitterroot Forest has declined significantly in the last decade, forcing administrative reorganization, reduction in personnel, and shifting priorities.
- Accompanying reductions in funding for management have been changes in the mix of goods and services the public demands from the Forest.
- Changes in federal land management policies over the years have created uncertainty about the direction that agency leaders may take.

The above seven contextualizing factors serve to make the environment for research and management complex (messy as we argue in the report), pointing out deep deficiencies in social science research and its relevancy to management.

Social Science Research Themes

We note that social science research concerning the Bitterroot National Forest is not extensive, and many of the findings are several years old. This conclusion is not to fault any one; given the extremely limited funding for this type of research and the general low priority that it is given in most management situations, we were not surprised.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Stephen F. McCool is a Professor, School of Forestry, University of Montana, Missoula, MT 59812. James Burchfield is an Associate Research Professor and Director of the Bolle Center for People and Forests, School of Forestry, University of Montana, Missoula, MT 59812. Wayne Freimund is an Associate Professor and the Director of the Wilderness Institute, School of Forestry, University of Montana, Missoula, MT 59812.

Our review of research identified four major themes, each with its own set of findings.

First, one primary area of research has dealt with public attitudes toward the Bitterroot National Forest and its management of the landscape. In general, attitudes tend to be bi-modal, with the majority of the public satisfied, but a substantial minority dissatisfied. Yet this research demonstrates that the dissatisfaction with management that has typified the agency over the last three decades continues to this day.

A second primary area concerns the relationships the Bitterroot Forest has with its publics. This research has focused on measures of successful public participation, views of consensus processes, evaluations of the use of sophisticated technology and computer models in public meetings, and suggestions for new methods of public participation. This research generally acknowledges the good faith attempts of the Bitterroot National Forest to improve its relationships, but also suggests, not surprisingly given the history of the Forest, that there is a ways to go.

A third area deals with investigations of recreation and wilderness users. This area of research points to two major findings: (1) the Selway-Bitterroot Wilderness has been used in several studies, but more because of its convenience to conduct research on specific wilderness user issues than to create understanding for management, and (2) visitors are generally satisfied with the level of facility development and recreation services available in recreation settings outside the wilderness.

The final area of research deals with the role of the Bitterroot National Forest in local economic development, particularly tourism. This area has not been well developed, but shows some disagreement about the acceptability of tourism development with valley residents.

Some General Conclusions About Social Science Research and the Bitterroot National Forest

We reviewed a number of social science research studies, yet we could not help but be struck by several characteristics of those studies. First, there have been between 35 and 40 such studies, a large number for many national forests. Those studies have led to lots of data for managers and planners to consider. Yet, because the studies were largely ad hoc in character and conducted at a variety of scales with few explicit connections among them, we have little formal knowledge of how the system works, nor do we understand the linkages among the various scales that influence management of Bitterroot National Forest resources.

We are impressed with the attempts by each of the scientists to conduct the individual studies in a credible, defensible manner. The studies were informed almost solely by the salient scientific disciplines, yet ecosystem-based management is organized around social values and goals, which are not discipline-based, but socially derived. This leads to a functional mismatch between the goals of ecosystem-based management and the orientation of social science research. We suspect that other research disciplines are confronted with similar questions.

While there are lots of studies in the file drawer concerning the Bitterroot National Forest and those studies have produced lots of data, we are troubled about the lack of knowledge these unconnected studies bring. Perhaps it is not so much the lack of knowledge as much as the illusion of knowledge that may occur when one views the stack of social science research. This illusion can be as much a barrier to understanding how the system works as the lack of knowledge.

Research Needs

Given the paucity of research, a more comprehensive and systematic social science research program oriented around the following themes would be useful in developing a better understanding of the interactions people have with natural resources in the Bitterroot National Forest:

First, the high rates of migration into the valley and the pace of social change suggest continuing conflict and controversy. Better understanding of the role of aesthetics and other amenities would help identify differences in attitudes toward the environment between newcomers and "old timers" and suggest possible ethical bases for conflict.

Second, in a county that is growing rapidly and has had difficulty developing a vision of its future where the Forest Service manages nearly three-quarters of the land, transboundary questions are important. Such issues include collaborative relationships, intergovernmental agreements, the significance of the three wilderness areas to the public, and how boundaries are perceived.

Third, much of the population growth is occurring near the national forest boundary, in the urban-wildland interface. Such population growth raises a number of significant questions with respect to fire suppression, use of fire as a management tool, habitat fragmentation, and access to the forest.

A fourth area concerns the planning and policy mechanisms to deal with contentious issues. How do people cope with policy change? What institutional arrangements are available to enhance learning and establish venues for safe and secure discussion of land management? Is the forest planning process appropriate to the type of messy situation the Bitterroot Forest finds itself enmeshed in?

Finally, the recreational and wilderness resources on the forest are substantial, yet the knowledge base with respect to management of visitors is minimal. Research on visitors would help identify acceptability of management actions, motives and benefits from participation, and perceptions of popular use-limit techniques.

Conclusions

While we have proposed a comprehensive social science research agenda that addresses socially important questions, we are still concerned that this agenda is not linked to the other disciplines (such as hydrology, wildlife biology and landscape ecology) conducting research in the Bitterroot Forest. The issues confronting management of the forest are complex and cut across disciplines, yet are addressed, as in many other settings, with a disciplinary focus and emphasis. These problems are complex, they are contentious, and they are messy. Integrated research may provide the scientific basis for resolving many of them, but our current direction in research is to collect data first and ask questions (about its usefulness) later.

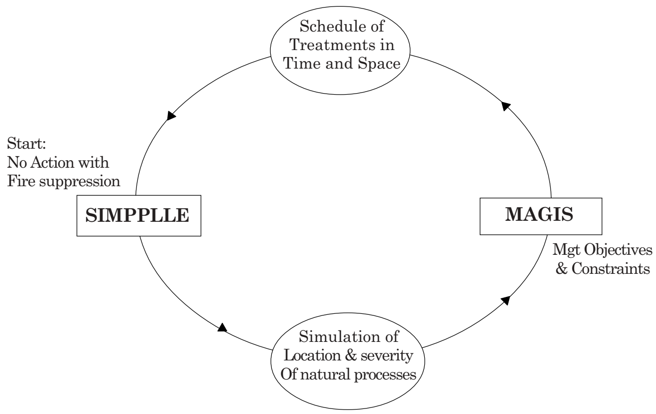
Integrated research (science involving a variety of disciplines simultaneously) is built upon understanding of the values in question, agreement about the problem, and stipulations about what disciplines can provide what type of information in what form and at what scale to whom. For example, focusing on defining successful public participation without understanding the knowledge basis of how ecosystems work and how that knowledge can be incorporated into a public involvement process has little long term application.

Since the questions the public asks are integrative in character, successful synthesis begins at the beginning. We are deeply concerned that without such a beginning, we will not achieve an acceptable level of understanding of the connections among the various parts to the system.

Reference

McCool, S.F.; Burchfield, J.; Freimund, W. 1999. Social Science Research And the Bitterroot National Forest: An Assessment and Synthesis. Missoula, MT: The University of Montana, School of Forestry. Technical Completion Report. RMRS-98504-RJVA. 48 p.

4. Implementation for Specific Landscape Areas



Analysis approach flowchart.

Stevensville West Central Study

J. G. Jones
J. D. Chew
N. K. Christianson
D. J. Silvieus
C. A. Stewart

Abstract—This paper reports on an application of two modeling systems in the assessment and planning effort for a 58,038-acre area on the Bitterroot National Forest: **SIM**ulating Vegetative **P**atterns and **P**rocesses at **L**andscape Sca**LE**s (SIMPPLLE), and **M**ulti-resource **A**nalysis and **G**eographic **I**nformation **S**ystem (MAGIS). SIMPPLLE was a useful model for tracking and analyzing an abundance of spatial data and processes, providing a good depiction of landscape patterns over time. Concerns were raised by Forest specialists about the predicted levels for a few of the fire and insect processes. MAGIS was an effective model for calculating watershed effects and some wildlife effects and was used to select some of the harvest treatments in the selected alternative. Problems in the application of MAGIS included the time needed for data cleaning and preparation, and the information projected for future stands provided a weak basis for estimating some wildlife effects.

Implementing ecosystem management requires managers to face a number of questions. What are the current conditions on the landscape and, in view of the important natural processes, how are they expected to change in the future? What are the desired conditions for the landscape? If the projected future differs from the desired conditions, what alternatives for treatment should be developed? Then, what effects are expected from the proposed treatments regarding extent and location of future natural processes, various resource values, environmental concerns, and economic and social interests?

Models and decision support systems can provide information and analyses to aid managers in addressing these questions (Mowrer 1997). The Landscape Analysis Group of the Bitterroot Ecosystem Management Research Project has participated in developing two landscape-level modeling systems: (1) **SIM**ulating Vegetative **P**atterns and **P**rocesses at **L**andscape Sca**LE**s (SIMPPLLE), a stochastic simulation model for projecting vegetative change as it is influenced by natural processes (Chew 1995), and (2) the **M**ulti-resource **A**nalysis and **G**eographic **I**nformation **S**ystem (MAGIS) for scheduling activities both spatially and temporally, given alternative management objectives and constraints (Zuuring and others 1995).

This paper reports on an application of these two modeling systems in the assessment and planning effort for the 58,038-acre Stevensville West Central (SWC) area on the Bitterroot National Forest. This study was a cooperative effort among the Rocky Mountain Research Station, Bitterroot National Forest, and The University of Montana. The objective was to test the use of these models with Forest data in an interdisciplinary team environment. Specifically, we were interested in learning about the capabilities of these models for addressing key analytical support needs:

1. Defining the range of variability for the analysis area, including capabilities, restoration goals and desired conditions.
2. Describing a sustainable landscape, what site-specific ecological characteristics and processes must be present to meet restoration goals.
3. Designing cost effective management practices that meet restoration goals and provide for people's needs for wood fiber, visual quality, recreation, etc., within the capabilities of the ecosystem.
4. Quickly examining the trade-offs among and between important ecological components and human desires and needs.
5. Assessing the ways to implement management practices while meeting forest plan goals and standards and other identified constraints.

The Planning Process

The planning process for the Bitterroot National Forest, like all National Forests, is directed by the National Forest Management Act (NFMA, 36 CFR part 219, 9/30/82) and the National Environmental Policy Act (NEPA) of 1969 (40 CFR 1500-1508). This specifies a two-level decision process. The first level involves decisions already made in the Forest Plan environmental impact statement and the next level involves decisions to be made in the site-specific NEPA analysis. Project planning involves two separate but linked planning processes, the NFMA Analysis and the NEPA Analysis. The steps in these processes are summarized in table 1. The NFMA analysis is not a decisionmaking process, but helps the responsible official review the decisions made in the Forest Plan and determine the purpose and need for action. This six-step analysis is completed to determine forest plan compliance, to identify opportunities

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

J. G. Jones is Research Forester and J. D. Chew is Forester, Rocky Mountain Research Station, Forestry Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807. N. K. Christianson is District Ranger, Stevensville Ranger District, Bitterroot National Forest, 88 Main Street, Stevensville, MT 59870. D. J. Silvieus was Interdisciplinary Team Leader, Stevensville Ranger District, Bitterroot National Forest, 88 Main Street, Stevensville, MT 59870. (Currently, District Ranger, Rifle District, White River National Forest, 0094 County Road 244, Rifle, CO 81650.) C. A. Stewart was Silviculturist, Stevensville Ranger District, Bitterroot National Forest, 88 Main Street, Stevensville, MT 59870. (Currently, Fire Ecologist, Lolo National Forest, Building 24, Fort Missoula, Missoula, MT 59804.

Table 1—Summary of steps in the NFMA (or EAWS) and NEPA processes.

Step	Description
NFMA and EAWS process	
1. Monitoring	Mid- and larger scale monitoring at the Forest or Regional level identifies needs for further study. Monitoring may also determine that there is a purpose and need for action, and a proposed action is developed, thus condensing or eliminating the NFMA analysis.
2. Location	The Bitterroot National Forest is divided into 32 study areas for forest plan implementation, with an average size of 65,000 acres. This is considered the fine scale assessment. Highest priority study areas are addressed first, with priorities determined by inventories, monitoring, and evaluations.
3. Existing conditions and characterization	Field data collection is used to document the existing conditions of resources. An assessment of private land conditions adjacent to National Forest land is also made.
4. Forest plan consistency, issues, and key questions	Existing resource conditions are compared to the Forest Plan standards and guidelines. Resource issues and resource sustainability questions are developed.
5. Desired conditions or reference conditions	Interdisciplinary team develops goals and objectives for the resources in the study area that are consistent with meeting Forest Plan goals and that are compatible with mid- and larger-hierarchical monitoring and evaluations. If desired conditions are not compatible with Forest Plan goals and objectives, an amendment may be proposed. The desired conditions or reference conditions can provide the framework for determining the purpose and need for action.
6. Opportunities and recommendations	Site-specific opportunities are identified for achieving the desired conditions. Short-term needs (1 to 5 years) are established, and the highest priority projects are taken into the NEPA process.
NEPA process	
7. Purpose and need for action	NEPA analysis is directly linked to the desired conditions or reference conditions described during the NFMA analysis or EAWS.
8. Proposed action	From the opportunities/recommendations developed in step 6, the highest priority site-specific project or set of projects will be evaluated for issues, effects and alternatives.
9. Scoping and issue identification	The formal process of informing the public of the proposed actions and the purpose and need for action, as well as requesting comments to determine the social, economic, and environmental issues is initiated.
10. Alternatives	Alternatives to the proposed action are suggested by the public and developed by the interdisciplinary team. They are responsive to the significant issues identified during scoping.
12. Environmental effects	The environmental effects of the proposed actions and the alternatives are determined and disclosed in the environmental document.
13. Decision	An alternative is selected. If the interdisciplinary team determines a finding of “no significant impact,” an Environmental Assessment is used and Decision Notice is published. If the selected alternative is found to have a significant impact on the human environment, an environmental impact statement is required and a Record of Decision is published.

for implementing the forest plan, and to identify areas where forest plan amendments are needed. Opportunities identified during this assessment that are high priority for short-term implementation become the proposed actions that are taken through the NEPA analysis (steps 7 to 12). The NEPA analysis is an effects analysis and is used to assist responsible officials in making good resource decisions. An interdisciplinary team of resource specialists interacts to assist in the decision process.

The Ecosystem Assessment at the Watershed Scale (EAWS) is an assessment similar to the NFMA analysis that is required by the Forest Plan Inland Native Fisheries Amendment of 1995 (INFISH) where actions may take place in watersheds that contain threatened or endangered fish species. Where an EAWS is required, it replaces the NFMA analysis and meets the same objectives, with an emphasis on watershed conditions. An EAWS was not completed for Stevensville West Central because there were no actions proposed within any Riparian Habitat Conservation Areas.

Public involvement is optional during the NFMA or EAWS process. It becomes a formal part of the process once proposed actions and the purpose and need for action have been identified and the NEPA process has begun. Then, a public scoping period begins and the issues that frame the analysis and the alternatives are identified.

The Stevensville West Central Area Analysis

The Planning Process for the Stevensville West Central analysis was guided by the Bitterroot Land and Resource Management (Forest) Plan and environmental impact statement, dated September 1987. The area analyzed was a section of the east slope of the Bitterroot Range, bordered on the west by the Montana/Idaho border and the east by the Bitterroot River (fig. 1). The major Management Areas and summary of their goals are:

Bitterroot National Forest	
Management Area 7—Selway-Bitterroot Wilderness	25,283 acres
Management Area 5—Emphasize motorized and nonmotorized semi primitive recreation and elk security	3,720 acres
Management Area 3a—Maintain "partial retention" visual quality objectives while managing timber	9,077 acres
Management Area 3c—Maintain "retention" visual quality objectives while managing timber	1,358 acres
Private lands	18,600 acres
Total area	58,038 acres

The private land was included for assessment purposes only; no management decisions were made for land in private ownerships.

Public participation, although optional during the NFMA or EAWS process, was a key component of the Stevensville West Central analysis. The public was involved in refining the goals and desired future conditions for the area. This involvement was formed around a collaborative working group that included interested publics, Bitterroot National Forest, Rocky Mountain Research Station, and The University of Montana. Over 20 public meetings and 3 public field reviews were completed. The group was able to agree on goals and develop desired conditions for all issue areas except for scenery management and roadless areas.

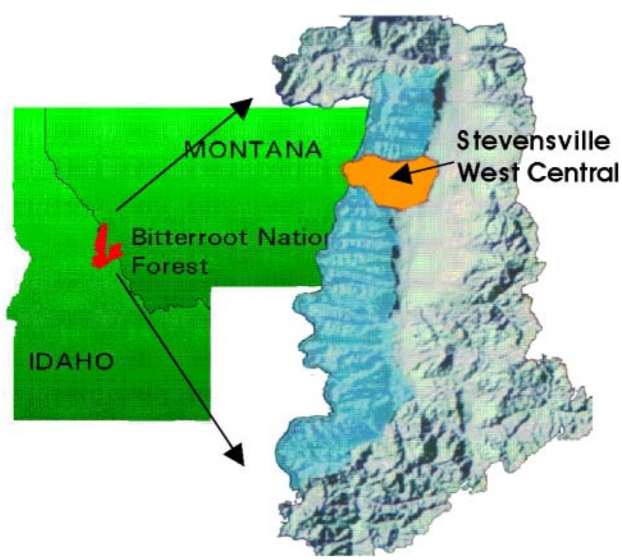


Figure 1—The Stevensville West Central Area.

The environmental issues associated with the proposed actions as well as those identified by the public centered around vegetation and fuels, wildlife, roadless lands, watershed and fisheries restoration, visual quality, recreation, and economic efficiency. Vegetation and fuels issues included the need to (1) restore and sustain historic structures and age classes; (2) restore species diversity; (3) restore fire; (3) alleviate forest health problems, including mountain pine beetle (*Dendroctonus ponderosae*), western spruce budworm (*Choristoneura occidentalis*), dwarf mistletoe (*Arceuthobium* spp.); and (5) the need to reduce intense wildfire risk. Wildlife issues included the need to restore vegetative conditions for elk (*Cervus elaphus*) habitat and old growth.

Five alternatives, including the Proposed action, were considered in detail:

1. No action.
2. Achieve desired conditions (proposed action).
3. Achieve desired conditions with wildlife corridors/distribution.
4. Achieve desired conditions in roaded lands.
5. Achieve desired conditions without commercial harvest.

The public suggested four more alternatives. These were considered, but not in detail:

6. Selection harvest only, no new roads.
7. Improve watersheds and fisheries without vegetation management.
8. Eliminate fire suppression.
9. Change visual quality objectives.

The NFMA analysis and ecosystem assessment was completed in September 1995, and the Environmental Analysis was completed in November 1996 (U.S. Department of Agriculture, Forest Service 1996). The decision was a modification of the Proposed Action alternative made to reduce harvest actions within the roadless areas and to improve the economic efficiency of the commercial timber harvests. The decision contained a comprehensive watershed and fisheries restoration program that included permanent road closures, road drainage improvements, and erosion prevention measures to reduce sediment; improvements for three trailheads; and the following vegetation treatments:

Precommercial thinning	1,160 acres
Commercial thinning	180 acres
Shelterwood harvest	20 acres
Sanitation/Salvage harvest	715 acres
Group Selection harvest	200 acres
Understory burning	4,615 acres
Whitebark pine burning	850 acres

The Friends of the Bitterroot, The Ecology Center, Alliance for the Wild Rockies, and American Wildlands filed appeals to the decision. The Regional Deciding Officer affirmed the decision. To date, a timber sale implementing the harvesting activities has been sold; understory burning has been accomplished on 2,879 acres; whitebark pine burning has occurred on 50 acres; and pre-commercial thinning has been completed on 117 acres.

Applications of SIMPPLLE

One of the models used in the Stevensville West Central analysis was SIMPPLLE, a stochastic simulation model that projects changes in vegetation over time and space by using a vegetative state/pathway approach (Chew 1995). A vegetative state is defined by dominant tree species, size class/structure, and density. These states are grouped by an ecological stratification of habitat type groups (Pfister and others 1977). Change between vegetative states is a function of disturbance processes. The probability of a process occurring in a given plant community is determined by both attributes of the state it is in and the vegetative pattern as identified by its neighboring communities in a unique landscape. The probabilities determined for each plant community in a landscape are used in a classical Monte Carlo method to simulate the location and timing of process occurrence. Once a disturbance process occurs for a plant community, logic is used to model its spread to neighboring plant communities. The application of SIMPPLLE in the Stevensville West Central area included the processes of western spruce budworm and mountain pine beetle in both lodgepole pine (*Pinus contorta*) and ponderosa pine (*Pinus ponderosa*), root disease, and three intensities of wildfire: light severity fire, mixed severity fire, and stand replacing fire.

The first application of SIMPPLLE in the Stevensville West Central analysis was to assist in quantifying the range of variability in processes and vegetative conditions. Multiple stochastic simulations with and without fire suppression, but with no management treatments, provided the basis for identifying averages and ranges in processes and vegetative conditions. Eight simulations were made with no fire suppression, and 30 simulations were made with fire suppression. The difference in number of solutions reflects differing estimates of the number of runs needed to quantify range of variability.

There are various ways to present and compare the results from these simulations to assist in quantifying the concept of range of variability. Figure 2 is a line plot of stand replacing fire. The output from the eight, five-decade simulations can be used to identify the range of occurrence for this process. However, a longer simulation for ten decades shows a possible different range of variation. In using SIMPPLLE, one has to consider the question of what time span is sufficiently long to address the concept of range of variability. Figure 3 displays the process of light western spruce budworm taken from the same eight simulations. There is less variability in this process, but a more definitive upward trend through about 7 decades in the future.

To evaluate the effect of fire suppression on this landscape, the average amounts of disturbance per decade for the processes were compared between the simulations with and without fire suppression. As expected, the average number of disturbed acres for the fire processes is notably higher without fire suppression (fig. 4). For acres disturbed by the insect and disease processes, the cumulative levels are compared. In contrast, the occurrence of insect and disease processes was higher in the simulations with fire suppression (fig. 5).

In addition to processes, the attributes of species, size-class/structure and density can be compared. Figure 6 compares the distribution of existing stand structure classes

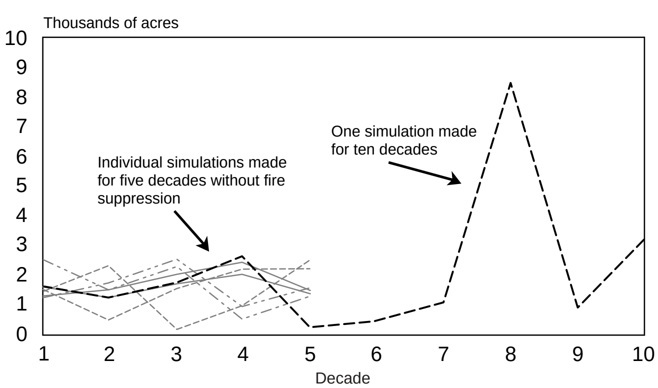


Figure 2—Acres of stand-replacing fire predicted in eight simulations with SIMPPLLE assuming no fire suppression and no management treatments.

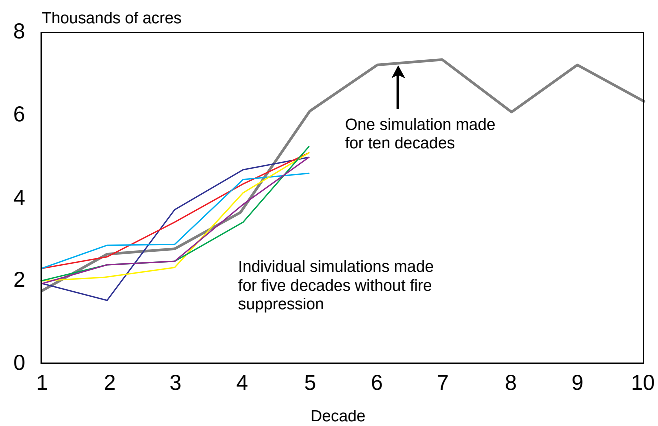


Figure 3—Acres of light infestations of western spruce budworm predicted in eight simultions with SIMPPLLE assuming no fire suppression and no management treatments.

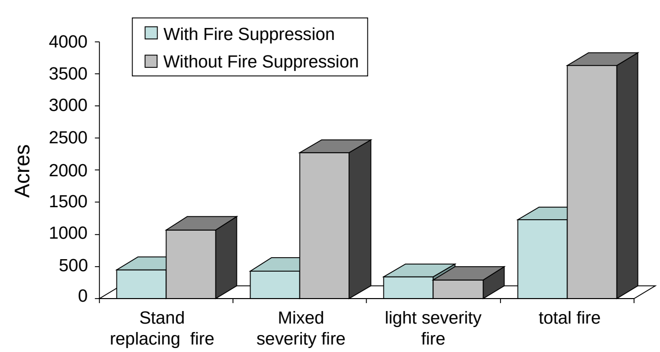


Figure 4—Average acres of disturbance per decade from SIMPPLLE simulations for "no action" with and without fire suppression for three fire intensities.

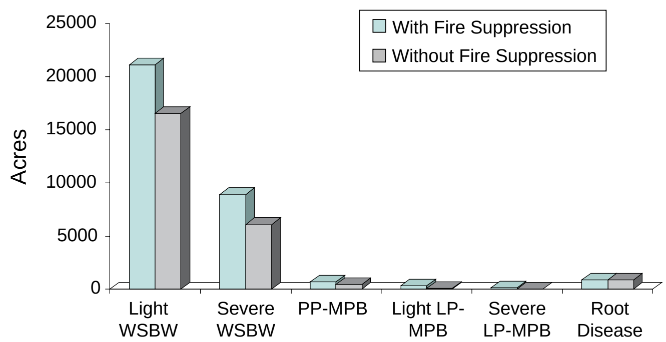
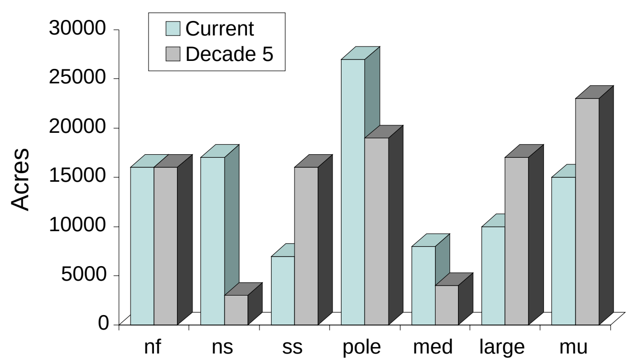


Figure 5—Cumulative acres of disturbance over five decades from SIMPPLLE simulations for "no action" with and without fire suppression for light western spruce budworm (light WSBW), severe western spruce budworm (severe WSBW), mountain pine beetle in ponderosa pine (PP-MPB), light mountain pine beetle in lodgepole pine (light LP-MPB), severe mountain pine beetle in lodgepole pine (severe LP-MBP), and root disease.



nf = nonforest ns = non stocked
ss = seedlings & saplings pole = 5" - 8.9"
med = 9" - 14.9" dbh large = 15" - 20.9" dbh
mu = multi-story

Figure 6—Distribution of existing stand structure classes compared with the distribution projected for the fifth decade from SIMPPLLE simulations with fire suppression but no management treatments.

with the distribution projected for the fifth decade as a result of only fire suppression and no other management activities. A significant percentage of the area is projected to move from the pole- and medium-size classes into the large- and multi-story-size classes. The increase in the multi-story class is of particular concern because of the increased probability for insect and disease processes associated with the shade tolerant species in the understory and because of the ladder fuels created by the understory species. The location of these multi-story stands, plus the location of the projected natural processes, can provide direction for designing treatment alternatives.

Once management alternatives were developed, SIMPPLLE was used to quantify possible amounts and locations of natural processes associated with those alternatives. Five simulations were made for each alternative that included the proposed treatments with fire suppression. Comparisons among the alternatives were made for the projected vegetation (species, stand structure, and density), and levels of disturbances processes. These projections can be presented as map displays showing spatial locations, as nonspatial frequencies for the disturbance processes, or compared numerically as acres disturbed, as in figure 7. The average level of occurrence of severe western spruce budworm for each alternative is compared to the range of variability from no management simulations (shown by the dots for each decade). The SIMPPLLE simulations display that the amount of severe western spruce budworm predicted for each of the alternatives exceeds the range of variability for the amount of budworm associated with no action and no fire suppression. The reason is these alternatives include fire suppression that prevents the fire processes from converting the high budworm hazard, multistory stands to other stand structures that are less susceptible to budworm.

Applications of MAGIS

MAGIS is a microcomputer-based spatial decision-support system. It is used for planning land management and transportation-related activities on a geographic and temporal basis in the presence of multiple and sometimes conflicting objectives (Zuuring and others 1995). MAGIS can be used in either optimization or simulation mode. In optimization mode, managers specify an objective to maximize or minimize and other objectives as constraints that must be achieved, and the solver selects the location and timing of activities that best meets these specifications and calculates the effects. In simulation mode, managers choose the location and timing of activities and use MAGIS to calculate the effects. Management Relationships within MAGIS are used to tabulate output quantities, acres with specified characteristics, and miles with specified characteristics, costs, and net revenues. Any of these can be calculated for an entire planning area or specific portions such as individual watersheds. Key Management Relationships developed in cooperation with District resource specialists were acres of hiding cover, acres of thermal cover,

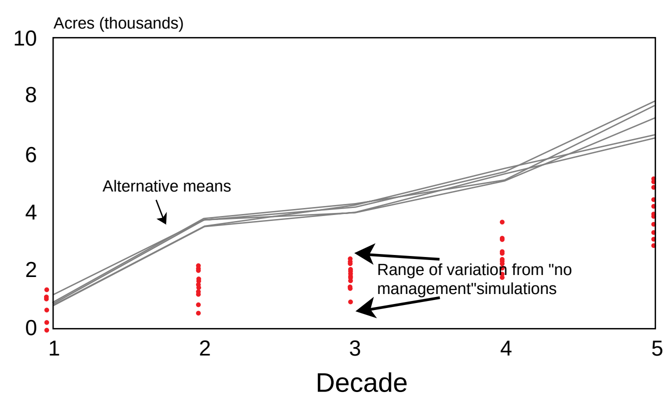


Figure 7—Average levels per decade of severe western spruce budworm from five SIMPPLLE simulations for each management alternative, compared with the dots showing the range of disturbance predicted for "no management."

a pine marten (*Martes americana*) habitat index, a pileated woodpecker (*Dryocopus pileatus*) habitat index, sediment yield, water yield, equivalent clear cut acres, and road impact factor. Ten year time periods were used.

In the plan for the Stevensville West Central study, MAGIS was to be applied in the process of developing the proposed action and management alternatives. Unfortunately, delays in completing the computer code prevented using MAGIS in this step of the analysis. As a result, the first application of MAGIS was to run it in simulation mode to compute the effects of the proposed action and each of the

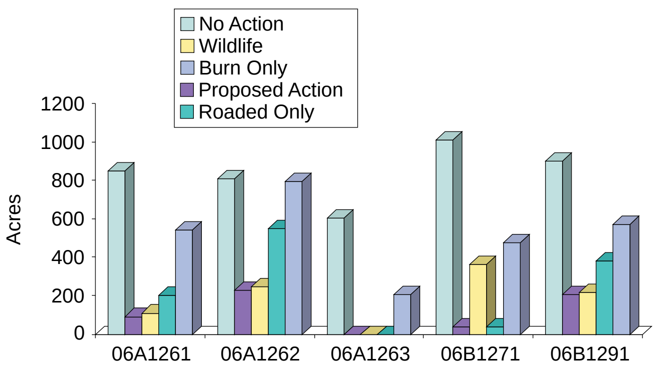


Figure 8—Acres of hiding cover by alternative for elected third order drainages calculated by MAGIS for the management alternatives.

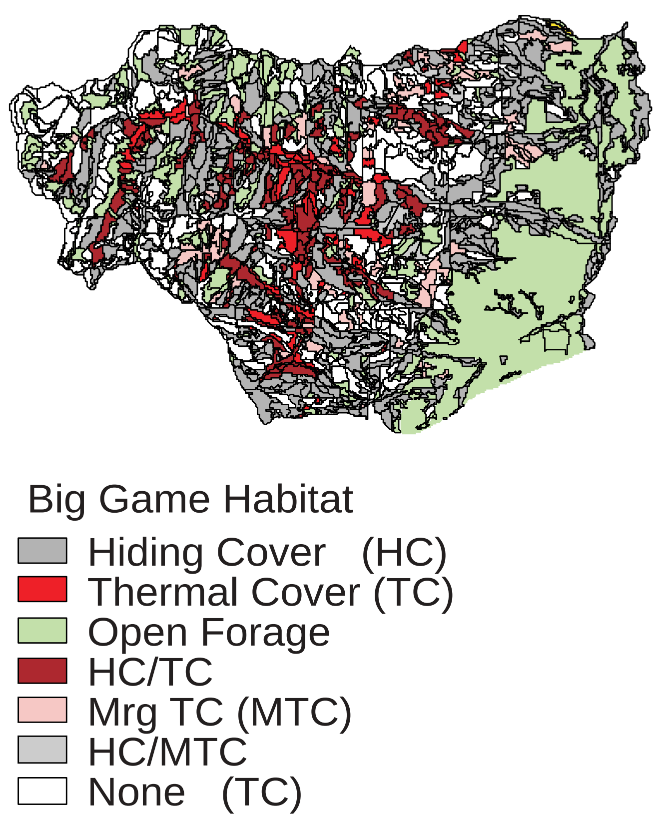


Figure 9—Location of various types o big game habitat computed by MAGIS for decade 1 of the "no action" alternative.

management alternatives developed by the interdisciplinary team. These effects were displayed numerically, as illustrated by the acres of hiding cover for the selected third order drainages presented in figure 8, and spatially, as illustrated by the big game habitat map displayed in figure 9.

Later in the process, MAGIS was applied in optimization mode to determine if the model could develop one or more management scenarios that improve on the previously developed alternatives. Four additional management scenarios were developed with the following specifications:

10. MAGIS proposed action.
    - Maximize present net value.
    - Harvest volume ≤ proposed action.
    - Wildlife habitat indexes and acreages ≥ proposed action.
    - Watershed impacts ≤ proposed action.
    - Maintain the underburn and precommercial thinning treatments specified for the proposed action.
    - No new roads or even-aged management harvest treatments.

11. No Helicopter yarding.
    - Specifications same as 1, except no helicopter yarding.

12. Minimize risk index.
    - Specifications same as 1, except minimize a composite risk index based on the frequency and type of disturbance predicted for the individual stands in the "no action" simulations made using SIMPPLLE.
    - Two MAGIS solutions were used to develop this scenario; the first minimized the risk index, and the second maximized present net value while holding the risk index to the value achieved in the previous solution.

13. Modified minimize risk index.
    - Specifications same as 3, except allow even-aged management harvest treatments.

Figure 10 compares the treatments selected in the Proposed Action with those selected in each of the four MAGIS scenarios. In general, fewer acres would be harvested in the each of the MAGIS scenarios than the Proposed Action. The other noteworthy trend was that the Minimize Risk Index

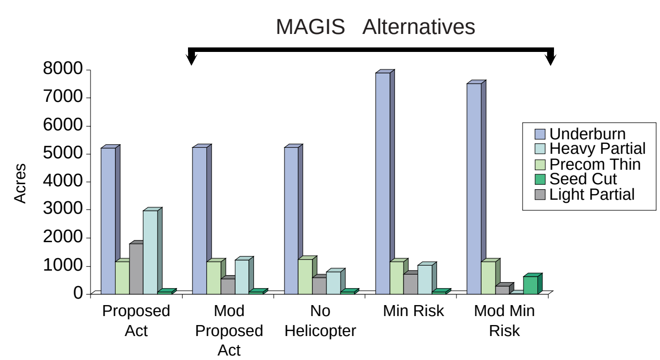


Figure 10—Acres by treatment type for the proposed action alternative compared with the scenarios developed using the MAGIS optimizer.

and Modified Minimize Risk Index scenarios would conduct underburning on approximately 2,000 more acres than the Proposed Action or the first two MAGIS scenarios.

The composite risk index multiplies the index assigned to a stand (from the SIMPPLLE simulations) times the stand acres and sums this product across all the stands. If a treatment is selected in a MAGIS scenario that addresses the risk for a stand, the post-treatment risk index is lowered accordingly. The composite risk index is approximately half that of "no action" for the Proposed Action, as well as the MAGIS Proposed Action and No Helicopter Yarding scenarios (fig. 11). The Minimize Risk Index and Modified Minimize Risk Index scenarios further brought the index value down to approximately 15 percent of "no action."

Present net value was negative for the Proposed Action and each of the MAGIS scenarios, although the Modified Minimize Risk Index scenario did show a positive return after the first decade (fig. 12). These negative present net values, or net costs, are due to the emphasis on ecosystem restoration. The MAGIS Proposed Action and No Helicopter Yarding scenarios had net costs approximately half those computed for the Proposed Action, while the net cost of the Minimize Risk Index scenario approximated the Proposed Action.

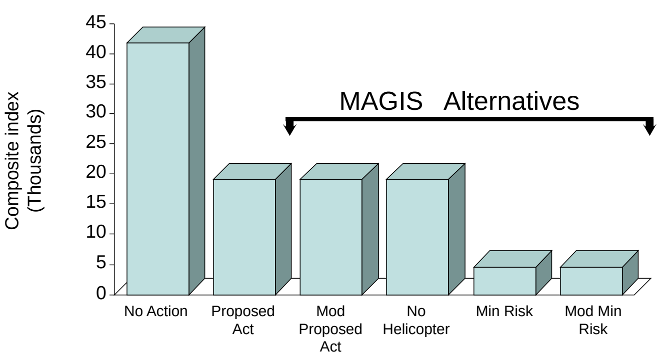


Figure 11—Risk index values for the "no action" and proposed action alternatives compared with the scenarios developed using the MAGIS optimizer.

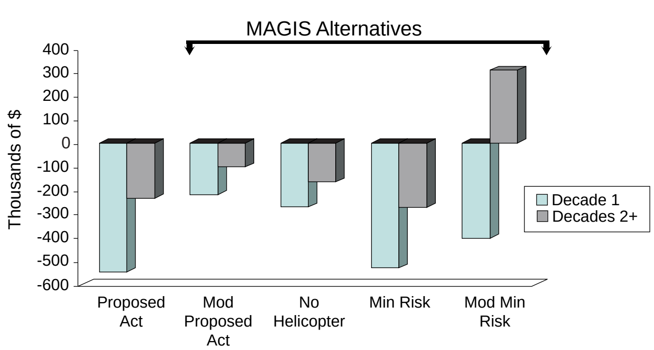


Figure 12—Present net value for the proposed action alternative compared with the scenarios developed using the MAGIS optimizer.

Discussion

Overall, the interdisciplinary team that developed the Stevensville West Central plan found SIMPPLLE to be a useful model for tracking and analyzing lots of spatial data and processes at one time. It provides the big picture of the interaction of natural processes working on a landscape over time and produces maps of landscape patterns over time. Past processes and adjacent processes and conditions are considered; it includes specific pest hazards, and it identifies problem areas. The processes involved in the model can be modified to reflect local conditions and knowledge. Data needs are simple and basic and are likely inexpensive. In addition, it provides a good public involvement tool to display various conditions and the effects of different management alternatives on the processes present on a landscape. The user interface/window system is easy to use and is being constantly improved.

Members of the interdisciplinary team identified several problems with regard to the fire and insect modeling included in the application of SIMPPLLE on Stevensville West Central area. Several members felt that the fire occurrence and intensity predicted for future decades was probably high in some instances, and the fire probabilities were higher than the fire occurrence data for large stands. They also believed adjustments were needed because the amount of mountain pine beetle activity predicted was probably low in mixed conifer stands, and the mortality of pole-sized trees is probably low during an epidemic.

Other problems were associated with data. Out-of-date stand data, a common condition, needs to be updated prior to modeling use. Also, stand exam data were not available for all stands, particularly those in the higher elevations and in the designated Wilderness. Data for these stands were based on air photo interpretation. In particular, this presented a problem in assigning these stands to a stand structure (size) class, which can be difficult to obtain from air photos.

Interdisciplinary team members expressed concerns that the current version of SIMPPLLE is polygon-based. That means that the logic for assigning processes is applied to the entire polygon. Either a polygon is assigned a process (the process is assumed to be present on the entire polygon) or it is not (the process is assumed to be totally absent from the polygon). It is likely that some processes operate on a scale smaller than an entire stand polygon.

Several system-related problems were also identified. Pathways and vegetation descriptions were not available at the time of the analysis, and the online help was not fully developed. SIMPPLE is currently only available on an IBM UNIX platform, while some would prefer a Windows version. Also, depending on the size of the IBM UNIX computer and use load placed on that machine, some significant computational time can be required to run SIMPPLE. The average time per time step (decade of analysis) in the Stevensville West Central analysis was five seconds, but this increases with number of polygons. For example, a model for another area containing 54,600 polygons required seven minutes per time step.

Many of the above problems have been addressed as of this writing. First, the fire process within SIMPPLLE has been redesigned to separate fire starts from the size or class of the fire. The fire probability data are designed to come from the National Fire Management Analysis System (NFMAS). Second, reprogramming key modules in SIMPPLLE has greatly increased its processing speed. Third, SIMPPLLE can now be run for either average or extreme fire conditions. Fourth, a raster-based version of SIMPPLLE is planned to address the potential problems of a polygon-based system.

The MAGIS model was used to predict water and sediment yield by watershed for the alternatives. This proved to be faster and more efficient than manually loading and running WATSED, a computer program commonly used in the Northern Region to compute watershed effects. The model also worked well for calculating equivalent clearcut area and road impact factors. A problem with the stand and compartment boundaries was they do not follow watershed boundaries, so stands had to be divided to stay consistent.

The model also calculated the wildlife effects for the alternatives including measures of big game habitat and indicator species habitat. This saved time and effort for the wildlife biologist's analysis. However, the lack of accurate stand data on snags and down woody material data hampered some of the wildlife effects calculations. This was particularly a problem when classifying stands as old growth, and the use of MAGIS to calculate old-growth acres had to be abandoned. Acceptable approximations were found for computing the other wildlife indicators.

The alternative eventually selected in the decision notice for the Stevensville West Central area was a modification of the original proposed action. The chosen alternative included some of the harvest treatments in the MAGIS Proposed Action scenario while others that were not selected in that MAGIS scenario were dropped.

The MAGIS Proposed Action scenario, as well as the other scenarios built via the MAGIS optimizer, could not be implemented in their entirety. The problem was that some unacceptable treatment and yarding options were included as candidate options for the polygons. Some of these unacceptable candidates were selected in the MAGIS scenarios. In future analyses, entering more precise rules for assigning the candidate options for the polygons could solve this problem. In particular, the assignment rules need to include cover type and ecology as criteria for selecting treatment options and need to integrate silvicultural logic to apply systems for specific habitats.

The use of MAGIS did result in time delays for completing the project analysis. As mentioned earlier, the cause of some of the delay was the program was not ready for production use when the analysis was begun. Some of the delay was caused by data preparation, a part of which was correcting and updating stand data. During the analysis, additional delays were caused by lack of communication regarding data needs. More modeling and computer applications help on the interdisciplinary team and closer communications with the research group would have helped the project stay within the NEPA schedule. Much of this was part of the learning process.

The vegetation projection method used in MAGIS was to apply growth rates to stand parameters: basal area per acre, volume per acre, average height, and average diameter. This caused several problems. First, these parameters were not available for all stands, and some had to be estimated by strata averaging methods. It became apparent in the latter stages of the analysis that not all members of the interdisciplinary team placed sufficient faith in these strata estimates. In particular, this was a problem in the MAGIS optimization scenarios, because the solver selected stands for harvest for which stratum averaging was used. This illustrates the importance of the interdisciplinary team having confidence in all the data and prediction methods.

Second, these projected stand parameters did not provide a good basis for predicting many of the wildlife effects associated with stands in the future. Information was lacking about the understory, down woody debris, and snags.

Third, this vegetation projection method differed from the vegetative state/pathway approach used by SIMPPLLE. As a result the two models provided somewhat different vegetation predictions.

Subsequent to this analysis, a vegetative state/pathway option for projecting vegetation has been added to MAGIS. This provides the advantage of using the same pathway relationships as SIMPPLLE, as well as the same stand information. Also, because vegetative states describe various aspects of vegetation, it is anticipated that this method will provide a better basis for predicting wildlife effects for future stands.

Recommendations for future applications include:

1. Applying MAGIS to landscapes where existing data are adequate, or allowing for time in the process for improving data to a level of acceptance by the interdisciplinary team.
2. Spending time at the beginning of the analysis for all team members to understand and agree on how the model will be applied.
3. Designating a member of the team the responsibility of running MAGIS in the analysis.
4. Using the vegetative state/pathway approach to minimize data requirements for projecting vegetation and enhance the potential for handling wildlife effects.
5. To the extent possible, minimizing data requirements for computing wildlife effects, by basing the effects calculations on vegetative states, as opposed to other stand attributes that must be supplied.

References

Chew, J.D. 1995. Development of a system for simulating vegetative patterns and processes at landscape scales. Missoula, MT: University of Montana; 182 p. Dissertation.

Mowrer, H. Todd, technical compiler. 1997. Decision support systems for ecosystem management: An evaluation of existing systems. Gen. Tech. Rep. RM-GTR-296. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 154 p.

Pfister, R.D.; Kovalchik, B.L.; Arno, S.F.; Presby, R.C. 1977. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 174 p.

U.S. Department of Agriculture, Forest Service. 1996. Stevensville West Central environmental assessment. Stevensville, MT: Bitterroot National Forest, Stevensville Ranger District.

Zuuring, H.R.; Wood, W.L.; Jones, J.G. 1995. Overview of MAGIS: a multi-resource analysis and geographic information system. Res. Note INT-RN-427. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 6 p.

Developing an Ecosystem Diversity Framework for Landscape Assessment

Robert D. Pfister
Michael D. Sweet

Abstract—Ecological diversity is being addressed in various research and management efforts, but a common foundation is not explicitly defined or displayed. A formal Ecosystem Diversity Framework (EDF) would improve landscape analysis and communication across multiple scales. The EDF represents a multiple-component vegetation classification system with inherent flexibility for a broad range of applications. Examples are drawn from experience in the Bitterroot Ecosystem Management Research Project to demonstrate concepts and applications. Continuing work will address integration of evolving protocols in western Montana.

A shared understanding of vegetation patterns at landscape scales is essential for implementing ecosystem management concepts. Classification and mapping are the primary tools for describing the existing vegetation conditions across a given landscape. However, if different classifications are used for each unique landscape, then we are faced with three problems: (1) integration for analysis of larger areas is difficult and uncertain, (2) communication is hampered, and (3) knowledge accumulated in relation to specific classes cannot be extrapolated to other areas.

Ecologists have been searching for the best, single, all-purpose classification system for the past century. Various task forces and committees have proposed universal, hierarchical classification systems that seek to address the issues of the time. Each are used and supported for a period of time until new needs for classification emerge. Then we go through the process of inventing a new classification protocol. Advances in information science and technology suggest designing classification systems with greater flexibility and inherent utility. Relational data bases provided the first breakthrough in organizing information to retain information content while offering unlimited combinations to simplify the abstraction of that information through classification. Geographic information systems incorporate that flexibility and apply it for explicit spatial relationships.

An Ecosystem Diversity Framework uses multiple classification systems in unique combinations to address different questions. Traditional ecosystem classification systems have been designed as multiple factor hierarchies, with different variables used at different levels of the classification. Although useful for many interpretations, the hierarchical ordering offers only a single, inflexible alternative. In contrast, an EDF will encourage development of standards for several, basic, relatively simple, classification components. Then, unique combinations of the components serve many needs for summarizing and displaying information by "types." The intent is to maintain the integrity of each component classification and afford versatility in designing more than one logical combination to simplify the complexity of ecosystems.

Integration and standardization of vegetation and habitat type classifications have been an ongoing dialogue with USDA Forest Service Northern Region specialists and BEMRP researchers during the past several years. Individually and jointly we have been in the learning process of integrating vegetation information across landscape scales and planning scales. The Ecosystem Diversity Framework is an attempt to synthesize many of these efforts in a format helpful for future landscape analyses.

Objectives and Scope

The objective of this ongoing study is to develop an Ecosystem Diversity Framework for western Montana that will have direct application to landscape assessment and planning on a broad range of ownerships. The purposes of this paper are to present the classification concepts, demonstrate some applications in BEMRP, and describe some logical next steps to complete the EDF.

Framework Concept and Components

The Ecosystem Diversity Framework is superficially similar to some previous classification systems. However, the emphasis is shifted from the final integrated classification to the essential components as building blocks. The EDF will be an explicit classification model combining many good ideas of the past in a format to efficiently meet current and projected future needs. Five components are currently being evaluated for incorporation in the EDF. Individual components can be defined at more than one level of resolution (preferably in a nested hierarchical fashion) to communicate at different levels of generalization and to link across different spatial scales. The five basic components are (1) Site, (2) Composition, (3) Successional Stage, (4) Vertical Structure, and 5) Density.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Robert D. Pfister is a Research Professor of Ecology and Michael D. Sweet is an Information Research Specialist, School of Forestry, University of Montana, Missoula, MT 59812; e-mail: rpfister@forestry.umt.edu; sweet@forestry.umt.edu

Site Classification

The primary method of site classification for vegetation interpretation in the western United States is the habitat type approach pioneered by Daubenmire (1952). Review of alternative groupings (Pfister and others 1977; Fischer and Bradley 1987; and Greene and others 1992) provides a basis for recommended standardization where appropriate. This component is technically not classification of existing vegetation but is directly derived from the late-successional vegetation types (associations—sensu Daubenmire). It provides a description of potential vegetation and also provides spatial stratification to understand (and display) how vegetation varies in relation to physical environments.

Composition Types

The Society of American Foresters (SAF) cover types (Eyre 1980) are almost exclusively single species dominance types (designed to be compatible with Forest Survey) for the eight Rocky Mountain States. Therefore, we are closer to a consensus starting point than many regions of the United States. They also are potentially similar to the National Vegetation Classification Alliances (Grossman and others 1998), if and when a workable, standard approach is used to define/identify them. Mixed-species types have been a nemesis for inventory, description, and mapping because of the extremely large number of possible combinations. Clearly, a standard protocol is needed that allows unambiguous definition, definitive inventory procedures, and consistent aggregation protocols to replace approximate "cross-walking" procedures.

Successional Stage

Structural stages that reflect changes in vegetation with time through natural successional processes have been described qualitatively in many ways. Age may seem the appropriate variable but is too expensive to inventory adequately. The traditional size classes of forest management have been adopted quite successfully with a few modifications for general utility. Several variations of subdividing this continuous variable have been proposed. Furthermore, diameter of the dominant/codominant layer seems preferable to quadratic mean diameter in order to establish a better relationship of dynamic change with age and to address stands containing multiple age classes.

Vertical Layering

This variable has become increasingly important for interpreting wildlife habitat, insect relationships (e.g., spruce budworm, *Choristoneura occidentalis*) and forest fire behavior (e.g., ladder fuels, fire severity). It is also of special importance as we increasingly manage for multiple aged stands with various forms of partial cutting practices. Although the classic examples of one-layer, two-layer, and three-layer stands are easy to visualize on paper, field identification is quite subjective. Standards for inventory and field identification are still in formative stages.

Density Types

This continuous variable has also been subdivided many ways. The Vegetation Subcommittee of the Federal Government Data Committee (FGDC 1997) and The Nature Conservancy (Grossman and others 1998) standards of 25 percent and 61 percent canopy cover are in general agreement with a long history of physiognomic literature (Penfound 1967; Mueller-Dombois and Ellenberg 1974). Subdivisions within these categories may be necessary for some applications to provide two, nested, hierarchical levels of density. For example, the Forest Service, by law, must recognize land with more than 10 percent canopy cover of trees as "forest land." On the other hand, the FGDC (1997) classifies lands with less than 25 percent canopy cover as "nonforest."

Integrating the Components for Multidimensional Perspectives

Each of the components can be viewed independently or in various combinations. The number of possible combinations from one-at-a-time to five-at-a-time provides 31 unique classification options. Varying arrangement of the axes for combined variables allows 325 unique visual configurations. This is one reason why we see so many unique ways of trying to classify the same thing. Should we ignore the many perspectives, attempt to force standardization, or embrace the diversity? We recommend a learning process of using flexibility as a powerful tool for communication and utilization of classification concepts. First, we can organize and simplify information complexity by using relational databases for inventory information on each component. Secondly, we can utilize Geographic Information Systems to provide visual displays of various combinations of components. This allows us to match appropriate information with each unique question and quickly abstract answers. It also provides for systematic development, storage, and access of knowledge as foundations for informed decisions. Furthermore, this kind of information system offers numerous opportunities for improving technical communication among disciplines, between researchers and managers, and between professionals and the public.

Historical Combinations of Components

A brief review of the literature provides several examples that implicitly used parts or most of this EDF. Daubenmire and Daubenmire (1968) first introduced two-way tables of distribution of Tree Species (Component 2—interpret as possible cover types) in relation to Habitat Types (Component 1) for northern Idaho and eastern Washington. A landmark summary of wildlife knowledge used a standard framework of 15 Ecosystem Types (Component 1) and 6 Structural Stages (Component 3) for eastern Oregon (Thomas and others 1979). A similar state-of-knowledge wildlife habitat summary used SAF Cover Types (Component 2), four Size Classes (Component 3) and three Density Classes

(Component 5) for the western Sierra Nevada in California (Verner and Boss 1980). The Northern Region of the USDA Forest Service also began building a regional wildlife database in the early 1980's using Habitat Types (Component 1) and Structural Stages (Component 3). A prototype study to define successional plant community types within individual major Habitat Types (Component 1) used Structural Stage (Component 3) and Plant Community Types (refinement of Component 2) to define types and pathways connecting the types (Arno and others 1985). State of knowledge summaries of fire ecology and succession formulated Habitat Type Groups (Component 1) and made use of Structural Stages (Component 3), Cover Types (Component 2) and Density (Component 5) for forests of western Montana (Fischer and Bradley 1987). Development of the SIMPPLLE model for predicting landscape pattern and processes used all of the components of the EDF to provide unique "states" within the object-oriented "expert system" pathway model (Chew 1995, 1997). Most of these components were also used in several ways at generally broader scales (coarser resolution) in the Interior Columbia River Basin Project.

A formal recommendation to use an "Ecosystem Diversity Matrix" to provide a practical coarse-filter approach for planning to conserve biodiversity was set forth by Hauffler, Mehl and Roloff (1996). Their ecosystem diversity matrix for the Southern Idaho Batholith Landscape included 11 Habitat Type Classes (Component 1), 10 Vegetation Growth Stages (each with 3 Density Classes) (Components 3, 4 and 5) to provide a two-dimensional 11 x 10 matrix. Within each cell, the potential major tree species were listed (Component 2). Once inventory has been translated to quantify the acres in the cells of the matrix, landscape analysis for biodiversity can begin. This includes estimation of adequate ecological representation with a species assessment, which helps lead to determination of the desired future condition.

Demonstration of the EDF Concept for Stevi-WC Resource Area

A post-facto demonstration was selected because many people have become familiar with the area through the BEMRP studies of the past five years. All of the five components were used in several different applications, but not always the same way. This is a common occurrence if a standard framework has not been provided at the start of a project. It seems appropriate to demonstrate the EDF for an area where we have an adequate database, familiarity, and an opportunity to use hindsight to ask the question: Would an EDF have improved our effectiveness?

A concerted effort was made in the first year of BEMRP to reach consensus on a vegetation classification system among several of the scientists. Standards were proposed but not universally adopted. A preliminary conclusion of this effort was that several researchers did not want to have their research efforts constrained by a standard classification, although consensus may be more important for managers doing landscape analysis (R. Pfister 1995 BEMRP Workshop Report). Although we did not have an explicit EDF for the collaborative work on the Stevensville-West Central (Stevi-WC) Integrated Resource Area, components of the proposed EDF were an implicit part of several BEMRP studies. The second purpose of this paper is to illustrate some uses that were made of the components and some potential uses that could have been made. Examples are drawn from collaborative work of the Stevi-WC I.D. Team and the Landscape Analysis Team (GIS, SIMPPLLE, and MAGIS).

Examples of Use of Components

Numerous examples were presented with colored maps in the oral symposium presentation and in a complementary poster presentation. Due to space constraints they are just listed in this paper. The first set of examples is used to illustrate sharing information about a specific landscape for each of the individual components. Both colored maps and summary tables of acres and percent of area by type are easily extracted from a GIS. The following components were displayed:

1. Eleven habitat type groups.
2. Twenty-nine composition types (species groups).
3. Five structural stages (size types).
4. Two layer types.
5. Four density types.

In addition, a display of combining components 3 and 4 displayed nine Size x Layer Types.

Applications From Components

Modeling Applications

All five components were used as part of SIMPPLLE (Chew 1995, 1997) and MAGIS (Zuuring and others 1995) model applications working with the Stevi-WC I.D. team. Two examples developed within the MAGIS applications were Thermal Cover from Components 3 and 5 and Hiding Cover from Components 1, 3, 4 and 5. Three examples from SIMPPLLE were Western Spruce Budworm Probability from Components 1 to 5, Stand Replacing Wildfire Probability from Components 1 to 5, and Bark Beetle Probability from Components 1 to 3 and 5. These disturbance process interpretations were initially abstracted from literature and expert opinion to provide probability of occurrence coefficients for stochastic pathway selections in SIMPPLLE (Chew 1995, 1997). The model also adjusts probabilities based on spatial stand adjacency relationships. Recently, a method was also developed to spatially display these relative probabilities for management interpretations of risk. Both of these models are being refined to provide greater compatibility in model input, presentation of information and linkage with GIS. The EDF is an integral part of these efforts.

Other Applications

The EDF provides for a consistent presentation of inventory information. The same kinds of interpretation incorporated in the above models can be made independently of the models. Interpretations can be made from the relational database through query routine, and spatial displays can be made directly from GIS. Sweet provided unique summaries of acres by types (Components 2, 3, 4, and 5) in 1996 for use by Fiedler and Keegan in their silviculture/economics BEMRP studies. Pfister also used this output for several intra-working group meetings.

Potential Applications

Specific Applications

As we learn the potential uses of information technology, we see a wide range of further interpretations that could be made for landscape assessment and planning. For example, a first approximation of Possible Old Growth could be obtained from a query of Components 1 and 3. Potential Forest Productivity (Yield Capability) can be estimated from Component 1 and refined by considering Component 2. Forage Production could be estimated from Components 1 and 5. The interesting challenge is to explore many other questions about ones landscape of interest using the powerful combination of classification and information technology. These could include locating potential opportunities for certain kinds of silvicultural prescriptions, ecosystem burning, wildlife browse production, and forest health. In addition, the EDF could be utilized in other model applications.

Mixed Ownership

Collaborative landscape or watershed assessment of mixed ownership presents a major challenge because of incompatible inventory information. A formal EDF should provide common ground at some level of resolution for shared analysis and interpretation.

Explicit Conditions

A major application of the EDF may be in moving toward explicit quantitative and spatial descriptions of Vegetation Conditions. This includes Historic Conditions, Existing Conditions, Alternative Future Conditions, Desired Future Conditions, and the explicit relations among them. These have been useful concepts that have not reached their full potential use because of our limited ability to communicate specifically what they mean relative to an entire landscape or specific locations within the landscape.

Biodiversity Planning

Availability of an EDF would have been very useful for the Biodiversity Discussion Group session held as part of the 1996 annual BEMRP Workshop. The work by Haufler and others (1996, 1999) would have fit right in then and remains just as important today. As they described, once existing acreage within cells of the “ecosystem diversity matrix” has been determined then specific landscape analysis of biodiversity leading to practical recommendations for Desired Future Conditions can begin.

Illustration of Framework

With a look to the future, we prepared an illustration of one possible way to integrate and display the five components in two dimensions. Figure 1 represents a modification of the Southern Idaho Batholith Landscape (Haufler and others 1996) to represent the Stevi-WC Landscape. It is presented as a partial vision of what might be used to illustrate an EDF for western Montana. In hindsight, we all might have benefited if we had this when we started BEMRP!

Framework Value

Approaching this as a framework, rather than a single multiple-factor classification, appears to have certain values. Information system technology allows many combinations of components for a wide range of applications. Maintaining the unique identity of each component in the database provides integrity. The level of inventory controls the precision of possible interpretation relative to each component, but aggregation of each component can be made for generalization at broader scales. For example, maps were displayed in the symposium presentation to show: 30 habitat types and phases aggregated into 10 habitat type groups aggregated into 4 “super groups.” Abstraction is a powerful tool for communicating with specialists from other disciplines and helping to provide public understanding of many of the broader level issues.

Standardization by Components

Emphasis for standardization should be placed at the component level to provide consistent building blocks for an EDF. Standardization is essential for comparing landscapes and aggregating information to larger landscapes or ecological regions. Standardization is more critical for components (technical) than for combinations (communication). Standardization of components may also be critical for modeling applications. Recommended standards for variables #3 to 5 are documented in a 1998 draft manuscript. Recommended standards for #1 (Habitat Types and Groups) and #2 (Composition) are being explored and will be forthcoming. These proposed standards might affect inventory protocols, model formulation, and the synthesis of knowledge.

Lessons Learned to Guide Formalizing the Framework for Western Montana

Formalization of the EDF requires coordination with evolving protocols by the Northern Region of the Forest Service, other agencies, and other land managers. Continuing work will incorporate the latest revisions of classification parameters used in the SIMPPLLE and MAGIS models. Continuing work will also incorporate and interact with the classification components of the Forest Service Draft Inventory Standards (4/99). Formalization also requires seeking

		Habitat Type Group						
		A		B		→	J	
Size Class	Structure Class	Density Class	Species[a]	Density Class	Species		Density Class	Species
Seedling - Sapling	Single	1	PP	1	DF		1	AL
		2	DF	2	PP		2	WB
		3		3	WL		3	AF
		4		4	LP		2	ES
Pole	Single	1	PP	1	DF		1	AL
		2	DF	2	PP		2	WB
		3		3	WL		3	AF
		4		4	LP		2	ES
	Multi	1	PP	1	DF		1	AL
		2	DF	2	PP		2	WB
		3		3	WL		3	AF
		4		4	LP		2	ES
Medium	Single	↓	↓	↓	↓		↓	↓
	Multi							
Large	Single							
	Multi							
Very-large	Single							
	Multi							

[a]PP = ponderosa pine, *Pinus ponderosa*; DF = Douglas-fir, *Pseudotsuga menziesii*; WL = western larch, *Larix occidentalis*; LP = lodgepole pine, *Pinus contorta*; AL = alpine larch, *Larix lyallii*; WB = whitebark pine, *Pinus albicaulis*; AF = subalpine fir, *Abies lasiocarpa*; ES = Engelmann spruce, *Picea engelmannii.*

Figure 1—Illustration of five components of an Ecosystem Diversity Framework for Stevi-WC area displayed as a two-dimensional matrix with density and composition components within each cell.

compatibility with evolving standards for the National Vegetation Classification System (NVCS) through the FGDC (1997), The Nature Conservancy (Grossman and others 1998), and the Ecological Society of America's Vegetation Classification Panel review draft to be released in July 1999. Work during the rest of this year will concentrate on components 1 to 2 as well as seeking compatibility with the above efforts. Continuing dialogue will be maintained with professionals on the Bitterroot National Forest, the Northern Region, and colleagues in BEMRP.

Summary and Conclusions

The Ecosystem Diversity Framework uses several component vegetation taxonomies that can be aggregated in many useful ways. The EDF is as powerful as the weakest link of component inventory information. The EDF helps abstract vegetation information for a wide variety of users. The EDF should be an integral component of inventory, GIS, models, assessment, and planning.

Acknowledgments

We wish to thank Barry Bollenbacher, Regional Silviculturist, USDA Forest Service, and Sue Heald, Ecologist, Bitterroot National Forest, for valuable review comments. This ongoing research is supported by the Bitterroot Ecosystem Management Research Project of the Rocky Mountain Experiment Station and the Mission Oriented Research Program of the Montana Forest and Conservation Experiment Station.

References

Arno, S.F.; Simmerman, D.G.; Keane, R.F. 1985. Forest Succession on Four Habitat Types in Western Montana. U.S. Gen. Tech. Rep. INT-GTR-177. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 74 p.

Chew, Jimmie D. 1995. Development of a System for Simulating Vegetation Patterns and Processes at Landscape Scales. Missoula, MT: The University of Montana. 182 p. Dissertation.

Chew, Jimmie D. 1997. Simulating Vegetation Patterns and Processes at Landscape Scales. In: Integrating Spatial Information Technologies for Tomorrow. Conference Proceedings from the Eleventh Annual symposium on Geographic Information Systems. 1997 February 17-20; Vancouver, British Columbia, Canada: 287-290.

Daubenmire, R. 1952. Forest vegetation of northern Idaho and adjacent Washington, and it's bearing on concepts of vegetation classification. Ecological Monographs. 22: 301-330.

Daubenmire, R.; Daubenmire, J. 1968. Forest Vegetation of Eastern Washington and Northern Idaho. Technical Bulletin 60. Pullman, WA: Washington Agricultural Experiment Station. 104 p.

Eyre, F.H. 1980. Forest Cover Types of the United States and Canada. Washington, D.C.: Society of American Foresters. 148 p.

FGDC (Vegetation Subcommittee) 1997. FGDC Vegetation Classification and Information Standards. Reston, VA: Federal Geographic Data Committee Secretariat. 31 p.

Fischer, W.C.; Bradley, A.F. 1987. Fire Ecology of Western Montana Forest Habitat Types. Gen. Tech. Rep. INT-223. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 95 p.

Green, P.; Joy, J.; Sirucek, D.; Hann, W.; Zack, A.; Naumann, B. 1992. Old-growth forest types of the Northern Region. R-1 SES 4/92; Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region.

Grossman, D.; Faber-Langendoen, D.; Weakley, A.S.; [and others]. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume I. The National Vegetation Classification System: development, status, and applications. Arlington, VA, USA: The Nature Conservancy. 126 p.

Haufler, J.B.; Mehl, C.A.; Roloff, G.J. 1996. Using a coarse-filter approach with species assessment for ecosystem management. Wildlife Society Bulletin. 24(2): 200-208.

Haufler, J.B.; Mehl, C.A.; Roloff, G.J. 1999. Conserving biological diversity using a coarse filter approach with a species assessment. In: Baydack, R.K.; Campa, H., III; Haufler, J.B., eds. Practical approaches to the conservation of biological diversity. Washington, DC: Island Press: 107-126.

Mueller-Dombois, D.; Ellenberg, H. 1974. Aims and methods of vegetation ecology. New York: John Wiley and Sons. 547 p.

Penfound, W.T. 1967. A physiognomic classification of vegetation in conterminous United States. Botanical Review. 33: 375-406.

Pfister, R.D.; Kovalchik, B.L.; Arno, S.F.; Presby, R.L. 1997. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 174 p.

Thomas, J.W., technical editor. 1979. Wildlife Habitats in Managed Forests the Blue Mountains of Oregon and Washington. Agriculture Handbook No 553. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 512 p.

Verner, J.; Boss, A.S. technical coordinators. 1980. California wildlife and their habitats: western Sierra Nevada. Gen. Tech. Rep. PSW-37. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 439 p.

Zuuring, H.R.; Wood, W.L.; Jones, J.G. 1995. Overview of MAGIS: A Multi-resource analysis and Geographic Information System. Res. Note. INT-RN-427. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 6 p.

Sequential Use of Simulation and Optimization in Analysis and Planning

Hans R. Zuuring
Jimmie D. Chew
J. Greg Jones

Abstract—Management activities are analyzed at landscape scales employing both simulation and optimization. SIMPPLLE, a stochastic simulation modeling system, is initially applied to assess the risks associated with a specific natural process occurring on the current landscape without management treatments, but with fire suppression. These simulation results are input into MAGIS, an optimization modeling system, for scheduling activities that reduce these risks and address other management objectives. The derived treatment schedules are utilized in additional SIMPPLLE simulations to examine the changes in risks and other natural processes. Treatment effects are quantified as changes in the predicted extent and frequency of occurrence of a specific natural process and the resulting economic benefits. An application involving the analysis of fuel treatments applied over time and space to reduce wildfire risks is presented to illustrate this modeling framework that utilizes the strengths of both simulation and optimization.

Management activities are being applied to address a host of resource problems. Frequently planners do not know what strategies are the most effective for answering the questions of HOW, WHEN, and WHERE to apply these treatments. Is it more effective to target the acres where the problem is most severe, but where the per acre treatment costs are very high? Or, is it better to target acres that are not now critical, but will become so in the future if not treated? Since the per acre treatment costs for these areas are less, more acres can be treated with the same budget. How can managers identify the conditions that are most effective to treat without addressing the spatial pattern of vegetation and how treatments will be applied over time? Ultimately, management activities must be planned and implemented in light of a variety of objectives and constraints that arise from the Forest Plan and are identified by Forest resource specialists and the public. Managers must be able to develop and evaluate alternatives that address the sometimes-conflicting objectives and constraints. This assessment of alternatives and the implementation of the selected alternative are carried out in a spatial context at the landscape level.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Hans R. Zuuring, corresponding author, is a Professor, School of Forestry, University of Montana, Missoula, MT 59812, e-mail: hrz@forestry.umt.edu, telephone: (406) 243-6456. Jimmie D. Chew is a Forester, and J. Greg Jones is a Research Forester, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 8089, Missoula, MT 59807, e-mail: jchew@fs.fed.us AND gjones@fs.fed.us, telephone: (406) 542-4171 and 4167, respectively.

Quantitative techniques are needed by which the spatial arrangement and timing of vegetation treatment options can be analyzed in the ecosystem landscape assessment and planning process. These techniques need to address the likely changes in the extent and frequency of occurrence of a specific natural process that result from management activities, the economic payoffs, and finally impacts on other resources.

Scientists and land managers in the Landscape Analysis Group of the Bitterroot Ecosystem Management Research Project (BEMRP) have developed and implemented a modeling framework that utilizes two modeling systems, SIMPPLLE and MAGIS, that interact with data in a spatial and temporal context. SIMPPLLE (**SIM**ulating Vegetative **P**atterns and **P**rocesses at **L**andscape Sca**LE**s) is a model that projects changes in vegetation over time and space using a state/pathway approach (Chew 1995). A vegetative state is defined by dominant tree species, size class, and density as well as association with a habitat type group (Pfister and others 1977). MAGIS (**M**ulti-Resource **A**nalysis and **G**eographic **I**nformation **S**ystem) is a microcomputer-based spatial decision support system (SDSS) for planning land management and transportation related activities on a geographic and temporal basis in the presence of multiple and sometimes conflicting objectives (Zuuring and others 1995). These models permit land managers to predict (1) vegetation change over landscapes, (2) change in the probability of disturbance processes relative to vegetation change, and (3) future effects on resource values.

The Approach

Although some analysts using a single modeling system approach have addressed the above problem, we have chosen to utilize two landscape-modeling systems that are integrated for project planning purposes. A simulator and an optimizer are employed and executed as separate entities that share information between them. In this way the resource analyst utilizes the strengths of both modeling systems (fig. 1).

The process begins by using SIMPPLLE to project the frequency and location of natural disturbances for the "no action" management alternative with fire suppression. These results are then utilized to compute a risk index for each stand, based on the most likely type of disturbance and the probability of its occurrence. This index is incorporated into a management relation, built in MAGIS, to evaluate resource treatments and their economic payoffs. Additional management relations that together comprise a planning scenario handle other issues. Examples of such relations are:

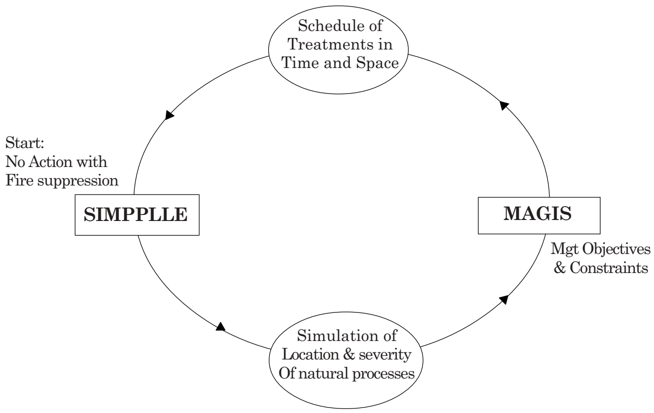


Figure 1—Analysis approach flowchart.

1. Acres in various stand size classes.
2. Equivalent clearcut acres by watershed.
3. Sediment production by watershed.
4. Big game hiding cover by third order drainage.
5. Pine marten (*Martes americana*) habitat index by third order drainage, and
6. Net revenues from several accounting stances.

Amounts are calculated for these management relations when MAGIS is run in either ***simulation mode*** (managers choose the location and timing of activities) or ***optimization mode*** (the solution process chooses the timing and location of activities based on the stated objectives). In most planning situations the analyst is usually interested in *minimizing* some risk index that has an adverse effect on resources subject to a set of constraining management relations while attaining a reasonable net revenue (not maximized but costs are at least covered by revenues). The solution yields outputs in the form of stand acres that are multiplied by their corresponding risk index and summed over all stands. In this manner a number of alternative planning scenarios, each consisting of a series of treatments applied over time and space, can be compared (based on certain criteria) to identify those alternatives that reduce or eliminate the risk. The schedule of activities proposed by MAGIS is imported into SIMPPLLE where additional simulations are run to evaluate the changes in location and extent of disturbances associated with these activities.

Methods

For years fire has been excluded from fire-dependent plant communities, which has resulted in excessive fuel buildups. Such unnatural accumulations of fuels present a hazard and increase the risk of catastrophic wildfire and their subsequent effects on other resources (Arno 1996b; USDA Forest Service 1996a). Historically, frequent, low-intensity ground fires modified some of these fire-dependent communities; stand-replacing crown fires occurred rarely if at all (Arno 1996a; Williams 1995).

The sequential approach of applying SIMPPLLE and MAGIS was used to analyze the effect of fuel treatments on the risk of wildfire and the economic consequences of such activities on the 58,084-acre Stevensville West Central area of the Bitterroot National Forest. SIMPPLLE and MAGIS applications were initially developed in cooperation with Forest staff and applied in an integrated resource analysis of that area (USDA Forest Service 1996b). The area includes 25,284 acres in the Selway-Bitterroot Wilderness, 14,155 acres of National Forest outside Wilderness, and 18,645 acres in private ownership. No treatments were proposed for the private land. It was included to capture interactions in functions and processes with adjacent National Forest lands.

The first step was to run stochastic simulations of SIMPPLLE over five decades for the "no action" management alternative with fire suppression. The number of acres impacted by four specific natural processes, and their associated frequencies of occurrence in stands located across the landscape, were computed. The four processes were (1) stand-replacement fire, (2) mixed-severity fire, (3) light-severity fire, and (4) western spruce budworm (*Choristoneura occidentalis*).

A risk index was developed to capture the relative importance of various natural processes and their frequency. This index can be thought of as a measure of undesirability of these processes, or alternatively, a prioritization for the application of fuel treatments. The weights assigned to this risk index are as follows:

Weight value	Risk source	Frequency of source
0	Stand not listed	
2	Light spruce budworm	≥ 50 pct
2	Mountain pine beetle (*Dendroctonus ponderosae*)	≥ 50 pct
4	Low probability of stand-replacing fire	1 - 10 pct
6	Severe spruce budworm	≥ 50 pct
8	Moderate probability of stand-replacing fire	11 - 20 pct
10	High probability of stand-replacing fire	≥ 20 pct

Figure 2 shows the distribution of these index weights based on the frequency of these processes on the landscape. For each stand, risk index weights were entered into MAGIS, and a risk index management relation was constructed. This risk index management relation multiplies the risk index assigned to the stand by the stand acres and sums this product across the stands as follows:

$$\text{Risk index management relation} = \sum_{a}\sum_{b}\sum_{c} r_{asp} * X_{asp}$$

where:

X_{asp} = Acres of stand ***s*** receiving treatment option ***a*** in decade ***p***,

r_{asp} = Risk index value in decade ***p*** as a result of applying treatment option ***a*** to stand ***s***. For "no action," r_{asp} equals the index assigned by SIMPPLLE. If a treatment is undertaken that addresses the risk, r_{asp} following treatment is reduced accordingly.

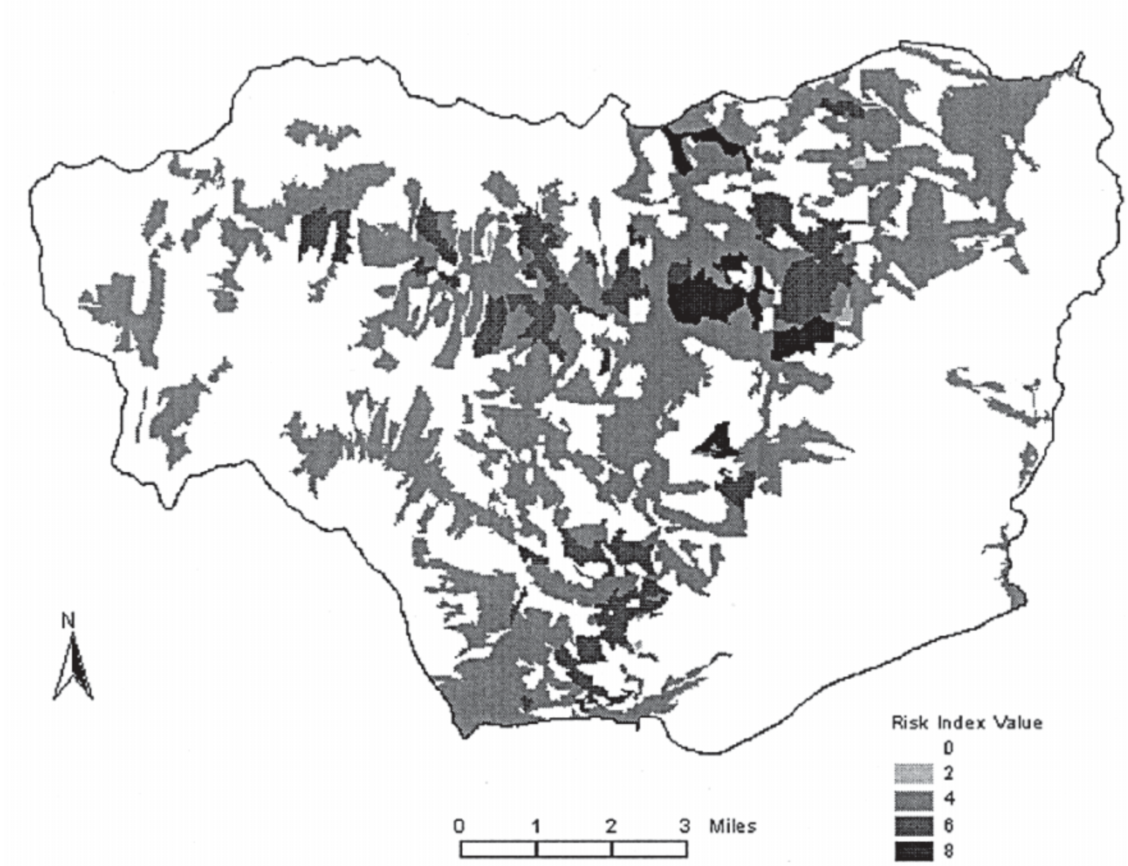


Figure 2—Map showing the spatial distribution of risk index based on natural processes occurring over 5 decades.

The next step was to run MAGIS in simulation mode to compute the risk index management relation value for the "no action" alternative. MAGIS was then used to develop four fuel treatment scenarios for the landscape (table 1). Scenarios 1 and 2 both permitted prescribed burning in the Wilderness area. They differed in that Scenario 1 required the risk index to be minimized in decade 1 while the timing was relaxed in Scenario 2 to minimize risk by decade 3. Fuel treatments for Scenarios 3 and 4 were limited to the 14,155 acres of National Forest outside the Wilderness, and water and sediment yields were limited to Forest Plan direction in six individual watersheds. Like the first two scenarios, they differed by the decade for minimizing risk index; minimize risk in decade 1 for Scenario 3 and decade 3 for Scenario 4. All four scenarios limited the volume of timber harvest per decade to 10,000 CCF (hundred cubic feet) or less, assuming that larger harvests would be politically unacceptable.

Each scenario was solved by first minimizing the risk index management relation for the specified decade, then achieving a second solution in which present net value was maximized while holding that risk index management relation to an amount slightly above the previously attained minimum value. The other conditions listed for the scenarios in table 1 were in effect in these solutions. This sequence develops an economically efficient scenario for minimizing risk while meeting the other scenario conditions. These solutions schedule treatments both spatially and temporally, as shown in figure 3.

Table 1—Specifications for four fuel treatment scenarios for the Stevensville West Central area.

Issue	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Prescribed fire permitted in wilderness	X	X		
Minimum risk index in decade 1	X		X	
Minimum risk index in decade 3		X		X
Water yield limits			X	X
Sediment yield limits			X	X
Harvest volume per decade <10,000 CCF	X	X	X	X

Results

Table 2 summarizes the results pertaining to the four scenarios mentioned above as well as the "no action" alternative. The risk index associated with the "no action" alternative was **93,196**. Scenario 1 reduced the risk index to **26,000** in decade 1, but with a net cost of **$2,518,000**. This scenario contained **14,856 acres** of broadcast burning in decade 1, as well as fuel treatments involving **306 partial cut** and **298 regeneration cut** acres that resulted in commercial timber harvests. Postponing the minimization

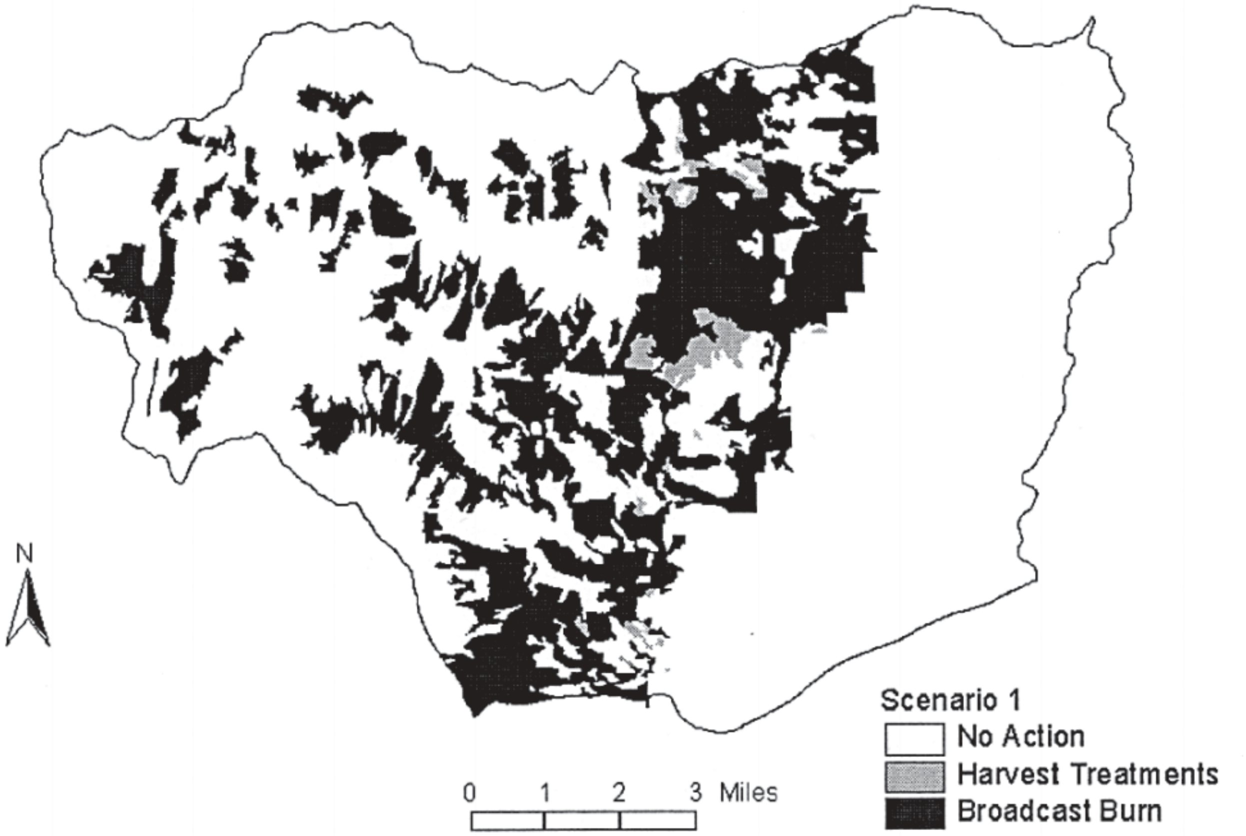


Figure 3—Map showing the spatial distribution of decade 1 burning and harvesting fuel treatments for Scenario 1.

Table 2—Summary of solution amounts for selected management relations "no action" and Scenarios 1 to 4.

			Scenario			
Management relation	**Units**	**No Action**	**1**	**2**	**3**	**4**
Present net value[a]	Thous $	0	–2,518	148	–608	979
Risk index for decade 1	Idex	93,196	26,000	90,637	52,000	91,042
Risk index for decade 3	Index	93,196	25,918	26,000	52,000	52,000
Harvest vol-decade 1	CCF	0	7,872	10,000	10,000	10,000
Harvest vol-decade 2	CCF	0	0	6,746	489	8,463
Harvest vol-decade 3	CCF	0	4,659	3,301	7,269	3,562
Underburning-decade 1	Acres	0	0	0	24	15
Underburning-decade 2	Acres	0	0	0	0	0
Underburning-decade 3	Acres	0	0	0	0	0
Broadcast burning-decade 1	Acres	0	14,856	0	8,526	0
Broadcast burning-decade 2	Acres	0	0	0	0	0
Broadcast burning-decade 3	Acres	0	0	13,711	0	7,556
Pre-commercial thin-decade 1	Acres	0	34	34	34	34
Pre-commercial thin-decade 2	Acres	0	0	0	0	0
Pre-commercial thin-decade 3	Acres	0	0	0	0	0
Partial cuts-decade 1	Acres	0	306	1,240	306	1,068
Partial cuts-decade 2	Acres	0	0	105	0	105
Partial cuts-decade 3	Acres	0	0	0	0	0
Regeneration cuts-decade 1	Acres	0	298	27	401	83
Regeneration cuts-decade 2	Acres	0	0	374	32	510
Regeneration cuts-decade 3	Acres	0	213	27	324	27

[a]Discounted at 4 percent.

of the risk index until decade 3 (Scenario 2) resulted in a positive present net value of **$148,000** associated with the treatments. When the broadcast burning was postponed until decade 3 the treated area was reduced by **1,145** acres as compared to Scenario 1.

For Scenarios 3 and 4, where fuel treatments are limited to only the public non-Wilderness area, the risk index was reduced to **52,000**. Broadcast burning reduced to **8,526** in decade 1 for Scenario 3 and to **7,556** acres in decade 3 for Scenario 4. Acres of fuel treatments involving timber harvests for Scenarios 3 and 4 approximated those for Scenarios 1 and 2. The fewer prescribed burning acres resulted in an improved financial situation with present net values **$-608,000** for Scenario 3 and **$979,000** for Scenario 4.

Next, the four management scenarios were entered into SIMPPLLE to model the effect of these treatment schedules on acres of stand-replacing fire (**SRF**), mixed-severity fire (**MSF**), light-severity fire (**LSF**), and western spruce budworm (**WSBW**), as well as the net effect on smoke production and fire suppression costs. Twenty simulations were run for five decades for each scenario. With regard to SRF, the pattern over the 5 decades for Scenarios 1 and 3 is similar to "no action," but with approximately **200** fewer acres burned on the average (fig. 4). For Scenarios 2 and 4, SRF acres are initially higher than "no action," decrease substantially for decades 2 to 4, and then level off. Scenarios 1 and 2, which treat Wilderness acres, result in fewer acres of SRF from decades 3 to 5.

For MSF, all the fuel treatment scenarios showed about the same number of acres in decade 1 as "no action" (fig. 5). After decade 1, Scenario 1 showed the most reduction in acres burned relative to "no action" and remained among the

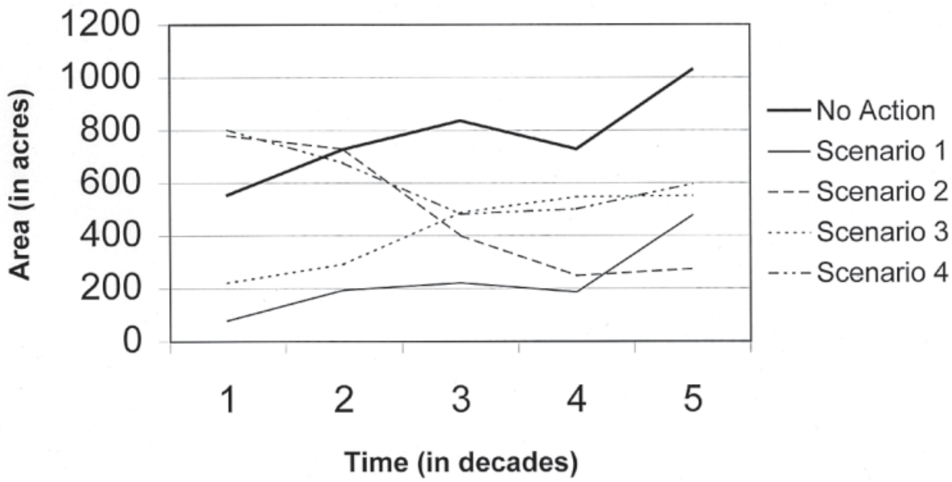


Figure 4—Estimated mean number of acres affected by stand-replacement fire over five decades.

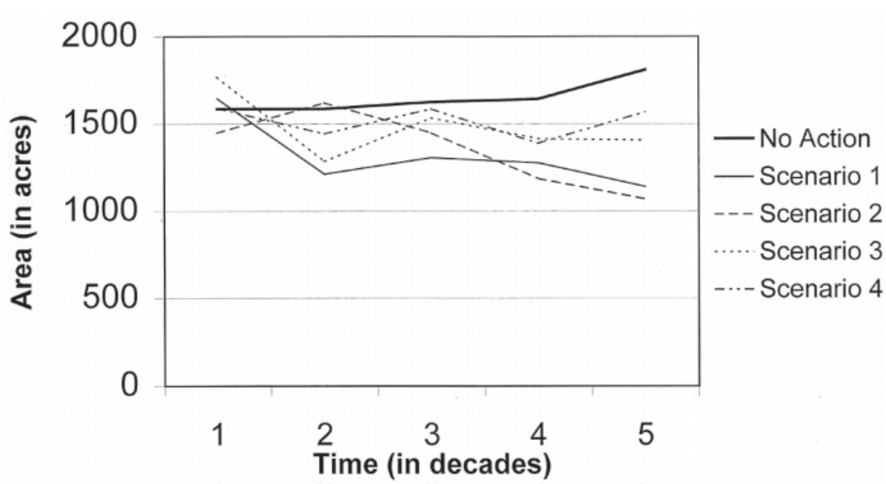


Figure 5—Estimated mean number of acres affected by mixed-severity fire over five decades.

lowest over the 5 decades. Scenarios 3 and 4 also showed fewer acres burned, with acres burned over the 5 decades varying between "no action" and Scenario 1. Interestingly, Scenario 2, which rose above "no action" in burned acres in decade 2, eventually had the fewest MSF acres by decade 5.

For LSF, the pattern of fire associated with fuel treatment scenarios was dependent on whether risk was minimized in decade 1 or 3 (fig. 6). For Scenarios 1 and 3 (minimize risk in decade 1) the burned acres were very low, but rose to approximate the "no action" acres by decades 2 and 3. For Scenarios 2 and 4 (minimize risk in decade 3), the initial LSF acres exceeded "no action," then dropped to almost zero by decade 3, then increased to approximate "no action" by period 4.

With regard to severe WSBW, Scenarios 1 and 3 (minimize risk in decade 1) exhibited a sharp decrease in the mean number of acres infested in decades 1 to 3 relative to "no action" (fig. 7). Scenarios 2 and 4 (minimize risk in decade 3) began with the number of infested acres only slightly less than "no action," but decreased to approximate the low level of severe WSBW of the other scenarios by decade 3. Severe WSBW remained low for all scenarios after decade 3.

Discussion

Several trends were observed from the four treatment scenarios. As might be expected, substantially fewer acres of the modeled natural processes were occurring in the initial decade for the scenarios where risk was minimized in decade 1 (Scenarios 1 and 3). The scenarios with risk minimized for decade 3 (Scenario 2 and 4), however, were approaching Scenarios 1 and 3 by decade 3 for most processes.

The scenarios having fuel treatments applied in Wilderness (Scenarios 1 and 2) did result in fewer total acres of undesirable natural processes over the 5 decades. The differences were most distinct for stand-replacing fire and mixed-severity fire, and minor for light-severity fire and severe western spruce budworm. It is interesting to note that by decade 5, Scenario 2 had the fewest acres for each of the four modeled natural processes.

The difference in net fuel treatment cost was substantial between the scenarios minimizing risk in decade 1 versus decade 3. The difference was that minimizing risk in the later decade provided the opportunity to implement more

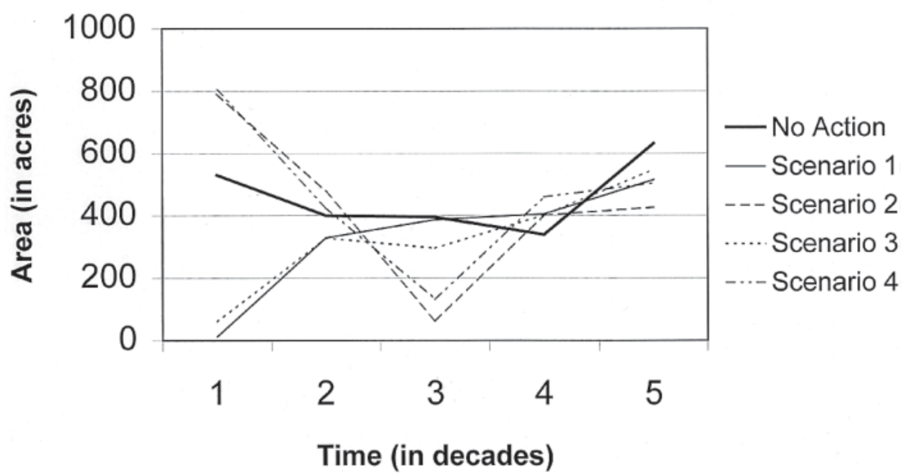


Figure 6—Estimated mean number of acres affected by light-severity fire over five decades.

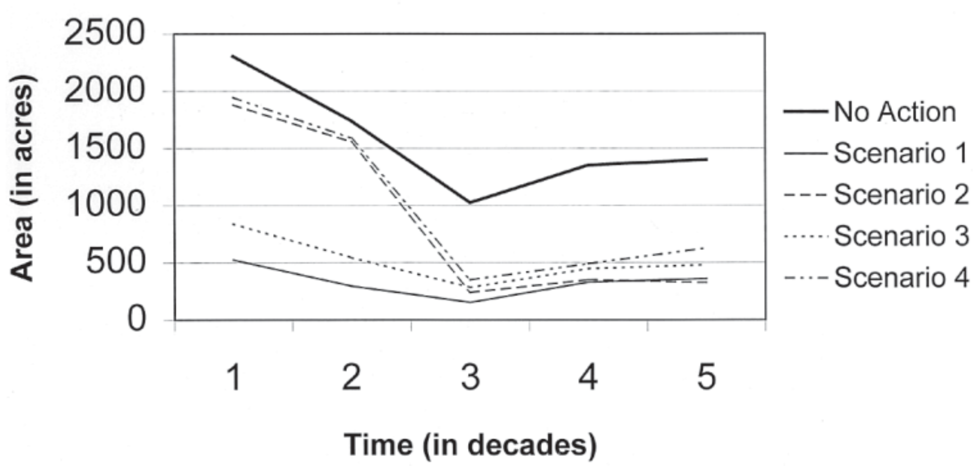


Figure 7—Estimated mean number of acres affected by severe western spruce budworm over five decades.

fuel treatments in the form of commercial timber harvests. This provided revenue that offset costs to result in positive net revenues for fuel treatments in Scenarios 2 and 4.

Many more fuel treatment scenarios could be developed for the Stevensville West Central area and the tradeoffs measured in terms of costs and reductions in acres affected by various processes. The real value of this and other modeling approaches is to identify and measure tradeoffs so that more informed decisions are possible. The integration of simulation and optimization models such as SIMPPLLE and MAGIS has great potential for developing spatially specific fuel treatment scenarios for landscapes and effectively quantifying the tradeoffs associated with those scenarios. This provides the opportunity to better understand, manage, and monitor forested landscapes.

References

Arno, S.F. 1996a. The Concept: Restoring Ecological Structure and Process in Ponderosa Pine Forests. In: Hardy, C.C.; Arno, S.F., eds. The Use of Fire in Forest Restoration. Gen. Tech. Rep. INT-GTR-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 37-38.

Arno, S.F. 1996b. The Seminal Importance of Fire in Ecosystem Management—Impetus for This Publication. In: Hardy, C.C.; Arno, S.F., eds. The Use of Fire in Forest Restoration. Gen. Tech. Rep. INT-GTR-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 3-5.

Chew, J.D. 1995. Development of a System for Simulating Vegetative Patterns and Processes at Landscape Scales. Missoula, MT: University of Montana. 182 p. Dissertation.

Pfister, R.D.; Kovalchik, B.L.; Arno, S.F.; Presby, R.C. 1977. Forest Habitat Types of Montana. Gen. Tech. Rep. INT-GTR-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 174 p.

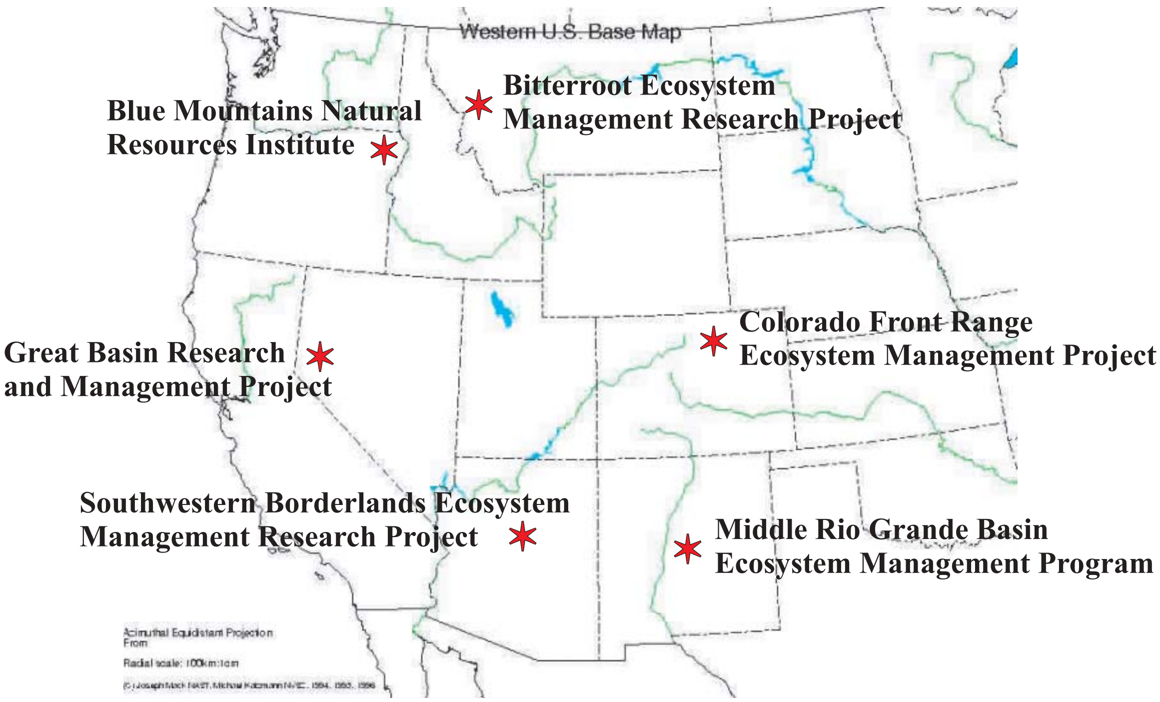
U.S. Department of Agriculture, Forest Service. 1996a. Land Management Consideration in Fire-Adapted Ecosystems: Conceptual Guidelines. FS-590. Washington, DC: U.S. Department of Agriculture, Forest Service, Fire and Aviation Management. 23 p.

U.S. Department of Agriculture, Forest Service. 1996b. Stevensville West Central Environmental Assessment. Stevensville, MT: U.S Department of Agriculture, Bitterroot National Forest, Stevensville Ranger District.

Williams, J. 1995. Aligning Land Management Objectives with Ecological Processes in Fire-Dependent Forests. In: Covington, W.W.; Wagner, P.K., tech. coords. Conference on adaptive ecosystem restoration and management: restoration of Cordilleran conifer landscapes of North America. Conference Proceedings. 1996 June 6-8; Flagstaff, AZ. Gen. Tech Rep. RM-GTR-278. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 32-34.

Zuuring, H.R.; Wood, W.L.; Jones, J.G. 1995. Overview of MAGIS: A Multi-resource analysis and Geographic Information System. Res. Note. INT-RN-427. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 6 p.

5. Overviews of Other Ecosystem Management Research Projects in the West



Source of background map: http://www.for.nau.edu/~alew/west-us-h.jpg

Achieving Ecosystem Management in the Borderlands of the Southwestern United States Through Coordinated Research/Management Partnerships

Gerald J. Gottfried
Carleton B. Edminster

Abstract—This paper provides a brief overview of the Southwestern Borderlands Ecosystem Management Research Project. Much of the research program was described in more detail, along with results thus far, in a conference presented in January 1999. Conference proceedings are documented by Gottfried and others (1999). The focus of the project is research on restoring natural processes, improving the productivity of grasslands and woodlands, providing wildlife habitat, and sustaining an open landscape, viable rural economy, and social structure.

The Southwestern Borderlands Ecosystem Management Research Project was initiated in 1994. The project was the result of a successful proposal by Dr. Leonard DeBano (retired, Rocky Mountain Research Station) and Larry Allen (Malpai Borderlands Project Coordinator, Coronado National Forest). One of the major factors in the success of the proposal was the support of the Coronado National Forest, the Malpai Borderlands Group, the Animas Foundation, The Nature Conservancy, the Natural Resources Conservation Service, the Bureau of Land Management, and The University of Arizona, School of Renewable Natural Resources.

The Borderlands project area of southeastern Arizona and southwestern New Mexico is a unique, relatively unfragmented, landscape of nearly one million acres containing exceptional biogeographic diversity in a series of natural communities ranging from semidesert grasslands and woodlands to mixed conifer forests. Maintaining the health and productivity of these natural communities is of critical importance in maintaining viable local rural economies. The geographic area of focus for the Borderlands Ecosystem Research Program is the San Bernardino Valley, San Simon Valley, southern Peloncillo Mountains, Animas Valley, and the Animas Mountains of southeastern Arizona and southwestern New Mexico. The project area is under multiple ownership and administration with 53 percent being in private ownership, 23 percent in state ownership (Arizona and New Mexico), 17 percent Coronado National Forest land, and 7 percent Bureau of Land Management land.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Gerald J. Gottfried is Research Forester and Carleton B. Edminster is Project Leader, Rocky Mountain Research Station, 2500 South Pine Knoll Drive, Flagstaff, AZ 86001, e-mail: ggottfried@fs.fed.us, cedminster@fs.fed.us

Much of the information gained from this project can be extended to the management of the larger Madrean Archipelago biogeographical region located in southern Arizona, southwestern New Mexico, and northeastern Sonora and northwestern Chihuahua, Mexico.

Results from the project contribute to the scientific basis for developing and implementing a comprehensive ecosystem management plan for the Borderlands area. In this plan, strategies are included for restoring natural processes, improving the productivity of grasslands and woodlands, providing wildlife habitat, and sustaining an open landscape, viable rural economy, and social structure.

Problem areas for the research project are:

1. To provide the scientific basis to establish the desired future condition for the planning region based on the highest quality biological science integrated with desired future social and economic conditions within the context of private and agency partnerships.
2. To plan and implement a long-term systematic program of basic and applied research and coordinated monitoring to integrate past and future research findings and contribute to developing guidelines for sustaining a viable rural economy and open landscapes.

International Conferences

In collaboration with the University of Arizona, the Borderlands Research Program conducted a conference on the biodiversity and management of the Madrean Archipelago in September 1994. The purpose of the conference was to bring together scientists and managers from government agencies, universities, and private organizations to examine the biological, cultural, and physical diversity and management challenges of the region to provide a basis for developing the research program. International regional conferences on fire effects and management strategies, March 1996, and the future of arid grasslands, October 1996, were also held in collaboration with the University of Arizona and the University of Sonora, Mexico. Proceedings of these conferences have been published as General Technical Reports RM-264, RM-289, and Proceedings RMRS-P-3.

Research Strategy

The strategy for accomplishing the research program has been to develop a comprehensive, multi-disciplinary synthesis of the status of our knowledge, identify research and monitoring needs and priorities, and define critical studies and field experimentation. The results of these analyses provide the basis for future research activities and also provide managers with a comprehensive reference of our current best available knowledge.

A series of initial investigations have been completed which summarize and synthesize information on topic areas having significant management and research planning applications. These efforts include:

1. Status of knowledge on the role and importance of human and natural disturbances on plant communities in the Borderlands of the United States and Mexico.
2. Status of wildlife information in the Borderlands ecosystem project area and proposed experimental design to address research and management needs.
3. Prehistory and early history of the Borderlands ecosystem: archeological synthesis and research recommendations.
4. Comparative research on integrated watersheds at Walnut Gulch, Arizona; the Gray Ranch, New Mexico; and other southwestern watersheds.
5. Development of an annotated bibliography for the northern Madrean biogeographic province.

A second program focus is the development of a comprehensive landscape inventory and monitoring system to serve research and management needs. Studies ongoing or being concluded include:

1. Mapping current vegetation of the Borderlands ecosystem management area using thematic mapper satellite imagery with intensive ground validation.
2. Delineation and interpretation of geomorphic surfaces of the southwestern Borderlands area. This study, along with vegetation mapping and soils mapping by the Natural Resources Conservation Service, will provide the basis for developing vegetation management strategies.
3. Land use history, historical landscape change, and photographic monitoring of the Borderlands region.
4. Contributing to development of a digital archive for studies at the Santa Rita Experimental Range. This project will create a geo-referenced archive of research records for the oldest range experiment station and will provide a basis for data management in the project area.

A third program focus is specific research studies identified as having high priority in filling knowledge gaps. These studies include:

1. Fire regime reconstruction in the southwestern Borderlands.
2. Effects of fire frequency on nutrient budgets of grasslands in the Borderlands area.
3. Understanding the spatial pattern of fire regimes and fire behavior at landscape scales, including comprehensive fire regime reconstructions. These studies are regional in scope and in cooperation with the Coronado, Cibola, Gila, Santa Fe, and Lincoln National Forests.
4. Effects of prescribed fire on birds and vegetation and selected endangered species in the Borderlands area. These studies are being conducted in landscape scale management areas on the Baker Burn area of 1995 and the Maverick Burn area of 1997 in the Peloncillo Mountains. Additional studies include effects of prescribed burning on Palmer agave (*Agave palmeri*) and foraging interactions with lesser long-nosed bats (*Leptonycteris curasoae*), survival and behavior of montane rattlesnakes (*Crotalus* spp.), remote sensing and GIS techniques for mapping and analyzing fuels, fire behavior, and effects on plant communities in the burn mosaic.
5. Cultural and environmental history of the Borderlands. This study provides the implications of past land use history for future management.
6. Experimental treatments, including mechanical treatments and prescribed fire, to investigate various vegetation and livestock management strategies. The objectives of these treatments are to improve composition and productivity of perennial native grasses, reduce shrub encroachment, and to improve soil properties and wildlife habitat.
7. Archeological implications of revegetation treatments.
8. Techniques for fuels visualization, mapping, and fire spread modeling in selected areas of the Chiricahua and Huachuca sky island mountain ranges.
9. Developing riparian ecosystem recovery priorities for the Southwestern Region.

Future efforts will expand development of monitoring efforts and investigations of the effects of prescribed burning at the landscape scale on vegetation, wildlife, and soil properties; relating vegetation condition and response to soils and site conditions; adapting predictive models of fire behavior to prescribed burning in grasslands and woodlands; and continuing experimental treatments in restoring grassland savannas.

Partners

In addition to the Rocky Mountain Research Station, research partners include Agricultural Research Service, U.S. Geological Survey Desert Laboratory, The Nature Conservancy, New Mexico Natural Heritage Program, Arizona Nature Conservancy, Audubon Society, Desert Botanical Garden, University of Arizona School of Renewable Natural Resources, Laboratory of Tree-Ring Research, Departments of Geosciences and Geography and Regional Development, Arizona State Museum, Office of Arid Lands Studies, Arizona State University, New Mexico State University, University of New Mexico, California State University, Indiana State University, University of Oklahoma, Arizona Geological Survey, Society for Ecological Restoration, and Arid Lands Project. Private and management agency partners also include the Malpai Borderlands Group, the Animas Foundation, Coronado National Forest, Douglas Ranger District, Natural Resources Conservation Service, U.S. Fish and Wildlife Service, Bureau of Land Management, Arizona and New Mexico Land and Game and Fish Departments, Whitewater Draw and Hidalgo Conservation Districts, Fort Huachuca, and the Arizona Department of Corrections.

These partners and the many special people working with these agencies and organizations are the critical elements in making the research program successful. The project is a national example of how private citizens and organizations and public agencies can collaborate to ensure the health and future of large, open landscape areas.

Reference

Gottfried, Gerald J.; Eskew, Lane G.; Curtin, Charles G.; Edminster, Carleton B., compilers. 1999. Toward integrated research, land management, and ecosystem protection in the Malpai Borderlands: Conference summary; 6-8 January 1999; Douglas, AZ. Proceedings RMRS-P-10. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 136 p.

Great Basin Research and Management Project: Restoring and Maintaining Riparian Ecosystem Integrity

Jeanne C. Chambers

Abstract—The Great Basin Research and Management Project was initiated in 1994 by the USDA Forest Service, Rocky Mountain Research Station's Ecology, Paleoecology, and Restoration of Great Basin Watersheds Project to address the problems of stream incision and riparian ecosystem degradation in central Nevada. It is a highly interdisciplinary project that is being conducted in cooperation with the Humboldt-Toiyabe National Forest. The project's focus is unique in that it is examining the linkages between the watershed, riparian corridor, and riparian ecosystem scales, and is focusing on both the mid to late Holocene (last 5,000 years) and the Recent Period (last 100 years). Major objectives include examining the effects of climate change and natural and anthropogenic disturbance on the structure and functioning of watersheds and ecosystems, evaluating methods and criteria for determining the effects of both disturbance and management activities, and developing methods for restoring or maintaining watershed and riparian ecosystem integrity.

Riparian ecosystems constitute a vital resource in the arid Great Basin. Highly valued for livestock forage, recreation sites, and water for agricultural uses, they also provide critical habitat for animals and support most of the region's biodiversity. Because of their many uses, riparian areas in the Great Basin have been extensively exploited—over 50 percent are in poor ecological condition (Chambers 1995). Much of the degradation in these systems can be attributed to human-caused disturbance, including livestock grazing, road construction in the valley bottoms, mining activities, recreation, and alteration of upland ecosystems. However, it is becoming increasingly clear that both past and present climate change processes are influencing the response of watersheds and riparian ecosystems to natural and human disturbances (Chambers and others 1998). Restoring and maintaining the integrity of riparian areas and of the watersheds that support them requires understanding the effects of natural and human-caused disturbance and the potential for recovery. It also requires understanding the linkages between climate change processes and the effects of disturbance.

In the Great Basin, many of the riparian areas have exhibited major episodes of stream incision during the past 150 to 200 years. Changes in stream patterns and dimensions have occurred and, where incised, streams have been isolated from their floodplains. The size of stream-associated riparian ecosystems has decreased, and significant changes in the species composition of riparian areas have occurred due to the effects of both stream incision and livestock grazing. To address these problems, the Great Basin Interdisciplinary Research and Management Project was initiated in 1994 (Chambers 1995). The overall objective of the project is to achieve a better understanding of the structure and functioning of riparian ecosystems and watersheds within central Nevada, and to develop guidelines for maintaining or restoring their integrity. It is an interdisciplinary project that is being conducted by the Rocky Mountain Research Station's Ecology, Paleoecology, and Restoration of Great Basin Watersheds Project in close collaboration with the Humboldt-Toiyabe National Forest. Partners include the University of Nevada, Reno; the Nevada Biodiversity Initiative; Utah State University; Indiana University, Purdue University at Indianapolis; Layfayette University, Environmental Protection Agency, U.S. Geological Survey, Agriculture Research Service, and Fish and Wildlife Service.

The study area includes the Toiyabe, Toquima, and Monitor Mountain Ranges of central Nevada. Watershed elevations range from 1,850 to 3,200 m. This is an arid area and precipitation ranges from about 20 cm at the base of the watersheds to 50 cm at upper elevations. The wide, central valleys are characterized by salt desert vegetation. At low-mid elevations within the watersheds, Wyoming big sagebrush (*Atemisia tridentata wyomingensis*) communities are interspersed with Utah juniper (*Juniperus osteosperma*) and singleleaf pinyon pine (*Pinus monophylla*). At higher elevations, mountain big sagebrush (*Artemisia tridentata vaseyana*) and limber pine (*Pinus flexilis*) dominate. The stream systems are typically high gradient, narrow, and highly incised. While low flows in these stream systems are typically less than 0.02 m^3/s high flows can exceed 0.8 m^3/s. Peak runoff and most flood events occur during snowmelt in late May or June. Riparian vegetation consists of quaking aspen (*Populus tremuloides*), narrowleaf cottonwood (*Populus angustifolia*), river birch (*Betula nigra*), willows (*Salix* spp.), and meadow communities.

Objectives and Progress to Date

The project's approach is unique in that it is focusing on both the mid to late Holocene (last 5,000 years) and the Historic Period (last 150 years). Also, it is examining the linkages between the watershed, riparian corridor, and stream reach or riparian ecosystem scales. The studies address both basic questions that will increase our understanding of these ecosystems and applied questions that will allow us to effectively manage them.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Jeanne C. Chambers is a Research Ecologist, USDA Forest Service, Rocky Mountain Research Station, 920 Valley Road, Reno, NV 89512, e-mail: jchambers@fs.fed.us

Effects of Climate Change and Natural and Anthropogenic Disturbance

The effects of climate change and disturbance on our watersheds are being reconstructed by examining the vegetation and geomorphic histories of the Holocene (last 11,500 years) and period of record (last 50 to 100 years) (Chambers and others 1998). A highly interdisciplinary approach is being used that combines paleoecology, geomorphology, and vegetation ecology.

Vegetation History of the Study Basins—Woodrat middens are being used to determine plant species distributions and, thus, climate change from the end of the Pleistocene to the present. As part of the Project, we have sampled a total of 29 different strata from three woodrat midden locations (Chambers and others 1998). Midden strata range in age from 100 to 8,900 years before present (YBP) and, together with the modern community, include a total of 236 taxa. During the early to mid Holocene (11,500 to 5,500 YBP), the total number of plant taxa identified in the middens remained stable. With the onset of the Neoglacial (4,500 to 2,500 YBP), there was a reduction in desert shrub vegetation, high numbers of plant taxa, and an increase in tree ranges at middle to low elevations throughout the Great Basin. A severe drought (2,500 to 1300 YBP) followed the Neoglacial and taxa numbers decreased by 50 percent or more, desert shrub vegetation increased, and there was a regional decline in woodlands. Taxa numbers increased again in the Medieval Warm Period (1,300 to 900 YBP), and reached a peak during the Little Ice Age (550 to 150 YBP) which was a cooler, wetter period characterized by range expansion of both pinyon and juniper. Since the Little Ice Age, taxa numbers have again been declining.

Geomorphic History of the Study Basins—Stratigraphic analysis and detailed geomorphic mapping have been used to reconstruct the geomorphic history of the study basins (Chambers and others 1998). The vegetation and climatic patterns observed in the woodrat middens closely parallels the recent (mid to late Holocene) geomorphic history of the basins. During the cool, wet Neoglacial, there was little hillslope erosion and both the valley bottoms and streams were relatively stable, exhibiting little aggradation or degradation. However, the severe drought that followed the Neoglacial resulted in a change from relatively mesic to xeric vegetation and in increased runoff and sediment removal from the hillslopes. There was significant deposition of sediment in the valley bottoms and large side valley fans formed. During the Medieval Warm Period, there was little hillslope erosion and the streams exhibited only minor adjustments with the shift to moister conditions.

The most recent period of channel incision began at the end of the Little Ice Age before the arrival of European settlers, about 200 to 300 years ago. A lack of hillslope sediment production and the generation of sediment free runoff have caused the most recent channel incision. Incision is not uniformly distributed along the channel, but varies as a function of distance from alluvial fans or other features that constrict the valley floor. Fans are controlling local rates of entrenchment, keeping the active channel from developing an "equilibrium" gradient during the most recent phase of entrenchment. Thus, some stream reaches may be inherently unstable as a result of the depositional patterns within the valley bottoms that occurred approximately 2,000 years ago.

The side valley fans and other base level controls significantly affect stream gradient and depositional regimes and determine vegetation patterns within the riparian corridor. Stream reaches immediately above the alluvial fans or other base level controls are characterized by lower gradients, higher past or present deposition of fine materials, locally high water tables, and meadow ecosystem types. In contrast, higher gradients, coarser materials, confined water tables, and shrub or tree ecosystem types characterize reaches farther upstream of base level controls. When streams incise through the alluvial fans, the water tables in the meadows are often lowered, resulting in a decrease in the aerial extent of the riparian corridor.

Recent Stream and Vegetation Dynamics—Recent stream dynamics have been reconstructed by examining a series of permanently located stream transects and reconstructing flood/incision events using dendrochronology (Chambers and others 1998). Where recent stream incision has occurred, a series of gravel-dominated surfaces have been produced along the active channel that are inset below the valley floor. Willow stands of similar maximum ages occur on bars that are similar heights above the active channel bed. The maximum willow age within a stand is highly correlated with the timing of floods (1983, 1978, 1975, and 1973), indicating that the surfaces were colonized following incision by significant flood flows. These observations are consistent with data collected at permanently monitored cross-sections, which illustrate that during the past 6 years most of the entrenchment was associated with 1995 and 1998 flood events. Analysis of the cross-sectional data suggests that variations in channel incision and bank erosion are the product of the geomorphic setting with respect to valley constrictions, substrate characteristics, the biomass and life form of bank vegetation, and the size, age class and, thus, rooting density of the willows.

Hierarchical Classification of Basin Sensitivity—Our initial data indicate that the sensitivity of upland watersheds in central Nevada differs, and that the rates and magnitudes of geomorphic responses to natural and anthropogenic disturbances vary dramatically. We are currently examining the geologic, hydrologic and biotic factors that contribute to these. We are developing conceptual and applied models of how these factors influence basin response to natural and anthropogenic disturbance and, conversely, how they affect recovery potential. The product will be a hierarchical classification of basin sensitivity that can be used in managing the watersheds.

Methods and Criteria for Evaluating the Effects of Disturbance and Management Activities

Instream Flows and Groundwater Dynamics—Stream and groundwater flows are critical to maintaining riparian vegetation, but can be severely altered by water diversions and developments as well as by stream incision. We have examined the temporal and spatial relationships between hydrologic gradients, vegetation, and soils in central Nevada meadows to increase our understanding of the hydrologic regimes required to support riparian vegetation (Chambers and others 1999; Castelli 1999). As described above, our meadows occur primarily above alluvial fans. They exhibit hydrologic gradients with water tables ranging from the soil surface at the lowest elevation upstream of the fan to depths of 400 cm or greater at the upper end of the meadow complexes. In general, vegetation types include, from wettest to driest, the Nebraska sedge (*Carex nebraskensis*) meadow, mesic meadow, dry meadow, and sagebrush meadow. Plant species composition of the Nebraska sedge and mesic meadow is determined by depth to water table during the growing season, the time the depth to water table is less than 30 or 70 cm, and the degree days of anaerobiosis, while composition of the dry and sagebrush meadows is related to the range in depth to water table, elevation, the presence of shrubs, and aerial cover of gravel and litter. Indicator species for each type include Nebraska sedge (water tables 1 to 30 cm deep), Kentucky blue grass (*Poa pratensis*) and Baltic sedge (*Juncus balticus*) for the mesic meadow (water tables 90 to 149 cm deep); clustered field sedge (*Carex praegracillis*) and intermediate wheatgrass (*Agropyron intermedium*) (water tables 133 to 172 cm deep) for the dry meadow; and Douglas' sedge *(Carex douglassii),* bottlebrush squirreltail (*Elymus elymoides)*, and basin big sagebrush (*Artemisia tridentata tridentata*) for the sagebrush meadow (water tables 196 to 400 cm deep). Variables related to water table often respond more rapidly than vegetation following disturbances affecting water tables and should be measured along with indicator species.

Water Quality—We examined the dissolved sediments, turbidity, water chemistry, and water temperature of the major perennial stream systems in the Toiyabe range during both high and low flows for the past five years. The effects of roads crossings and cut banks on water quality were evaluated for four study drainages. The primary water quality problems within the drainages are suspended sediments and particulate matter. Several of the water quality variables, including suspended sediments, appear to be closely related to basin lithology, and this must be taken into account when monitoring water quality in these streams.

High Resolution, Low-altitude Video Imagery—As part of the project, we have evaluated the usefulness of low-altitude, high-resolution video imagery for rapidly assessing riparian corridors and ecosystems. Video imagery can be a useful tool for determining the major vegetation types within the riparian corridor and for obtaining certain stream geomorphic characteristics such as curvature and width ecosystems (Neale 1997). Vegetation types are most accurately classified when: (1) imagery is obtained in the fall and variations in vegetation coloration exist due to differences in leaf senescence and soil moisture availability; and (2) ground-truthing is used to verify the classification. Low altitude aerial photography compares favorably to resource scale aerial photography in terms of identification of major vegetation types. Video imagery does not allow quantification of understory vegetation or species composition and, thus, it cannot be used to assess ecological condition.

Methods for Restoring or Maintaining Watershed and Riparian Ecosystem Integrity

Mesic Meadow Restoration—Mesic meadows are among the most productive within the riparian corridor and are highly valued for wildlife habitat and livestock forage and as recreation sites. Consequently, they are often degraded. We have examined the plant physiological and community responses of degraded mesic meadows to determine (1) the effects of livestock grazing and nitrogen addition and (2) the response to potential restoration treatments, including soil aeration and revegetation (Martin 1999). Gas exchange and water potential measurements of two important mesic meadow species, Nebraska sedge and Kentucky bluegrass, and community rooting response were measured. Herbage removal had little effect, possibly because of the heavy use in the past. Nitrogen addition reduced root growth and accelerated plant phenology and, thus, may impede meadow recovery processes. Aeration increased root growth and photosynthetic activity, indicating that it can ameliorate at least some of the negative effects of grazing. Revegetation was ineffective due to unfavorable growing conditions for seedling establishment.

Dry Meadow Restoration—In many cases, degradation of riparian corridors has led to the dominance of basin big sagebrush. We have used two environmentally similar ecosystem types, dry meadows and basin big sagebrush/basin wildrye (*Leymus cinereus*) trough drainageways as models for evaluating the restoration of sagebrush dominated sites to dry meadows using alternative stable state concepts (Blank and others 1998; Linnerooth and others 1998; Linnerooth 1999). We conducted a restoration experiment in which we burned the sagebrush and seeded with dry meadow species on sites that exhibited different water table levels. Burning resulted in higher soil temperatures, higher levels of extractable nutrients, and higher soil water availability at deeper depths. Emergence and survival of dry meadow species was highest on sites with high water tables, during high precipitation years, and for species adapted to drier conditions. Our results indicate that sagebrush dominated sites with high water tables represent an alternative state of the dry meadow type and that restoration is possible.

References

Blank, R.R.; Chambers, J.C.; Linnerooth, A. 1998. Influence of prescribed burning on riparian soils in central Nevada. In: Potts, D.F., ed. Rangeland management and water resources: proceedings; 1998 May 27-29; Reno, NV: American Water Resources Association and Society for Range Management: 235-242.

Castelli, R. 1999. Soil plant relations along a soil water gradient in central Nevada riparian meadows. Reno, NV: University of Nevada. 47 p. Thesis.

Chambers, J.C. 1994. Maintaining and restoring riparian ecosystem integrity in central Nevada: An Interdisciplinary ecosystem management project. In: Diverse values—seeking common ground. Northwest regional symposia; 1994 December 8-9; Boise, ID. Moscow, ID: University of Idaho, Idaho Riparian Cooperative: 102-109.

Chambers, J.C.; Blank, R.R.; Zamudio, D.C.; Tausch, R.J. 1999. Central Nevada riparian areas: physical and chemical properties of meadow soils. Journal of Range Management. 52: 91-98.

Chambers, J.C.; Farleigh K.; Tausch, R.J.; Miller, J.R.; Germanoski, D.; Martin, D; Nowak, C. 1998. Understanding long-and short-term changes in vegetation and geomorphic processes: the key to riparian restoration. In: Potts, D. F., ed. Rangeland management and water resources: proceedings; 1998 May 27-29; Reno, NV: American Water Resources Association and Society for Range Management: 101-110.

Linnerooth, A.R. 1999. Restoring sagebrush dominated riparian corridors using seedling establishment to demonstrate alternative stable states. Reno, NV: University of Nevada. 60 p. Thesis.

Linnerooth, A.R.; Chambers, J.C.; Mebine, P.S. 1998. Assessing restoration potential of dry meadows using threshold and alternative state concepts. In: Potts, D. F., ed. Rangeland management and water resources: proceedings; 1998 May 27-29; Reno, NV: American Water Resources Association and Society for Range Management: 111-118.

Martin, D.W. 1999. Species interactions and recovery potentials of Nebraska sedge/Kentucky bluegrass meadows in central Nevada. University of Nevada, Reno. 121 p. Dissertation.

Neale, C.M.U. 1997. Classification and mapping of riparian systems using airborne multispectral videography. Restoration Ecology. 5: 103-112.

Research of the Rio Grande Ecosystem Management Program

Deborah M. Finch

Abstract—This paper describes the mission, objectives, and preliminary results of the Middle Rio Grande Ecosystem Management Research Program managed at the Rocky Mountain Research Station's Albuquerque laboratory. This program was initiated in 1994 to address growing pressures to effectively manage the limited resources of the middle Rio Grande Basin. The program is divided into four problem areas: upland vegetation, links between uplands and rivers, fish and wildlife, and cultural resources. This paper describes the productivity and products of the program since its inception.

Rio Grande Basin ecosystems have evolved under human influence for at least 12,000 years. Since 1540, the Middle Basin has experienced increasing environmental and socioeconomic changes, including urban population growth, invasion of aggressive exotic plants, water development, changes in rural economic patterns, shifts in public values, and endangerment of riparian species. Primary goals of the Middle Rio Grande Basin Ecosystem Management Program sponsored by the Rocky Mountain Research Station (RMRS) are to generate and share knowledge and methods to maintain the ecological health and diverse cultural and economic values of native grasslands, shrublands, and woodlands in the space- and resource-limited ecosystems of the Middle Basin.

Working with over 30 Basin stakeholders, our program coordinates and implements research designed to solve environmental and sociocultural problems in the Basin with emphasis on sustaining rangeland health, riparian productivity, fish and wildlife populations, archaeological sites, and human values and needs. An initial literature assessment of status and issues of river and upland ecosystems in the Rio Grande Basin was published by our program in 1995 (Finch and Tainter 1995). Research updates and cooperative ventures of the Rio Grande program were most recently highlighted at a symposium held June 2-5, 1998 cosponsored by RMRS and the U.S. Fish and Wildlife Service. Research products were summarized in the symposium proceedings, *Rio Grande Ecosystem: Linking Land, Water, and People. Toward a Sustainable Future for the Middle Rio Grande Basin* (Finch and others 1999).

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Deborah M. Finch is Project leader, Ecology, Recovery and Sustainability of Grassland and Riparian Ecosystems in the Southwest Research Work Unit, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 2205 Columbia Se, Albuquerque, NM 87111.

Environmental History and Cultural Dimensions

To interpret current ecosystem dynamics and health in the middle Basin, it was first necessary to understand and describe the influences of past human land uses during critical periods of New Mexico's complex history (Finch and Tainter 1995). Therefore, a comprehensive environmental history was funded by the program and published last year (Scurlock 1998). This environmental history report documents land change during the following periods: American Indian (pre-1540), Spanish Colonial (1540-1821), Mexican (1821-1846), Territorial (1846-1912), and Statehood (1912-present). Another volume reviewing the history of irrigation in the Middle Basin was also funded and published by our program (Wozniak 1998). Members of the program (Roy Jemison and Carol Raish, RMRS, Albuquerque, NM) are in the process of editing a book about livestock grazing in the Southwest, including an evaluation of historical, social and economic considerations. This volume has been accepted for publication in Elsevier Press and is due to be printed in the year 2000. A pilot project assessing social and economic costs and benefits of Hispanic ranching on national forests has recently been implemented under the auspices of the Rio Grande Program and is described in a recent article by Raish (1999). For more information on the economic role of livestock, see Raish (1998).

To visually document prehistoric human influences, our program is developing three-dimensional GIS models of reconstructed past landscapes using archaeological, vegetational, and paleoenvironmental data from the Rio del Oso drainage of the Santa Fe National Forest (Richard Periman, RMRS, Albuquerque, NM). Landscape models will be produced for three time periods, including two Puebloen occupations (1200-1325 and 1325-1600) and the historic Hispanic occupations (see Periman 1999). In addition, a Ph.D. project on this topic is underway at the University of New Mexico (UNM), and a dissertation should be completed by the year 2001. A summary of cultural research implemented by members of the Rio Grande Program team is included in table 1.

Ecological Disturbance and Restoration Research

Watershed and biological studies were initiated in FY94 and FY95 in the middle Rio Grande Basin, defined as the reach between Cochiti Dam and Elephant Butte Reservoir, New Mexico (table 1). Current studies are assessing responses of soil nutrients, water, belowground flora and fauna,

Table 1—Summary of current research implemented by the Rio Grande Program.

Riparian and watershed disturbance and restoration
Effects of drought, fire, and grazing on woodland-grassland interface
Landscape patterns in relation to lightning, precipitation, and vegetation
Cienega restoration in relation to road-engineering techniques
Methods for restoring grasslands using prescribed fire, vegetation manipulation, amendments, and grazing management
Classification of vegetation species composition and structure along the Rio Grande
Wildlife and fish
Status, distribution and ecology of Rio Grande cutthroat trout and other fish species
Maternal roost ecology of three bat species of concern
Arthropod-habitat relationships in the Rio Grande bosque
Stopover ecology of Neotropical migrants in the Rio Grande Valley
Migrant use of exotic and native vegetation
Willow flycatcher use of mowed channels and unmowed vegetation
Use of stable-isotope ratios in understanding bird migration
Cultural Dimensions
Economic, social, and cultural importance to Hispanic ranchers of livestock grazing on national forests
Ecology and current role of Anasazi cobblemulch gardens
Prehistoric and historic human influences on landscape development

herbaceous and woody plants, and fish and wildlife populations to (1) disturbances by drought, fire and its suppression, grazing, and past human activities, and (2) restoration treatments to mitigate or reverse disturbance effects.

Drought, overgrazing, and fire exclusion are three of the major factors, interacting in concert, that have resulted in degraded upland and river ecosystems in the middle Basin (Finch and Tainter 1995). Several cooperative studies were implemented to evaluate effects of drought, grazing exclusion, fire suppression, and historic human influence. These studies have involved the use of dating tree rings (Betancourt and Swetnam), landscape analysis (Potter, Milne, UNM), experiments with cobble rocks (White, UNM, Loftin, RMRS and Los Alamos National Lab), excluding cattle from streams (Valett, Moyer, Dahm, UNM), and current and historic inventory data and photo records at Research Natural Areas (RNA) (Muldavin, Ladyman, UNM Natural Heritage Program). Ecological assessments have detected widespread shifts in grassland/shrubland/woodland boundaries (Baisan and Swetnam 1997; Kieft and others 1998; Johnson and others 1999), influences of early Puebloan cobblemulch gardens on current ecosystem functioning (White and others 1998), effects of grazing and hydrology on nutrient composition and retention in streams (Valett and others 1998; Moyer and others 1998), and influence of RNA protection on ecosystem health as indexed by plant age and densities, nutrient cycling, and extent of cryptogam crusts (Ladyman and Muldavin 1996).

Evaluations of the influence of the 1950's drought on pinyon (*Pinus* spp.) demography are underway by Julio Betancourt (U.S. Geological Survey Desert Ecology Lab, Tucson, AZ) and Tom Swetnam (University of Arizona, Tucson). Their most recent update was published in Journal of Climatology (Swetnam and Betancourt 1999). In addition, the Rio Grande program sponsored a book about the 1950's drought in the Southwest that is being compiled and edited by Betancourt. A Ph.D. dissertation at UNM on the relationships between lightning strikes, precipitation, and landscape vegetation patterns was published in Landscape Ecology (Potter and others 1998).

A large number of cooperating agencies are involved in ecological disturbance and restoration research, in part because altered or degraded ecosystems are prevalent in the Basin, crossing organizational boundaries. Restoration ecology studies were designed to determine whether intervention with treatments will interrupt ecosystem degradation processes and re-establish natural ecological functioning (contacts: Carl White, UNM, Albuquerque, NM; Samuel Loftin, Los Alamos Research Lab, Los Alamos, NM; Roy Jemison, RMRS, Albuquerque, NM.). Recent results of amendment, road engineering, and prescribed fire studies have been published by White and others (1997), Pawelek and others (1999), Loftin (1999), and White and others (1999).

Biological Diversity Research

Understanding Basin ecosystems and cultures cannot be achieved without an understanding of the importance of the Rio Grande and its associated tributaries (Finch and Tainter 1995). The river itself has historically been and still is a major focal point for human settlement, water development, farming and irrigation, and pollution from local and upland sources. Despite threats from growing human populations, the Rio Grande and associated tributaries and streams continue to be important reservoirs for biological diversity in the Southwest. To understand the contributions of river and stream habitats to biological diversity, we implemented mapping and survey assessments and experimental studies of Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*), Rio Grande Sucker (*Catostomus plebeius*), and Rio Grande Chub (*Gila pandora*) (Bob Calamusso, New Mexico State University, Las Cruces and John Rinne, RMRS, Flagstaff); Neotropical migratory birds (Deborah Finch, Jeff Kelly, and Wang Yong, RMRS, Albuquerque); and endangered species (Southwestern Willow Flycatcher, *Empidonax traillii extimus*) (Deborah Finch, Scott Stoleson, Jeff Kelly, RMRS, Albuquerque) (table 1). Recent results have been published on fish status and distribution (Calamusso and Rinne 1999), stopover ecology of migratory landbirds (Yong and Finch 1997a; Kelly and others 1999), willow flycatcher migration (Yong and Finch 1997b; Finch and Kelly 1999), and brown-headed cowbird (*Molothrus aler*) distribution (Schweitzer and others 1998).

After further consultations with various agencies and stakeholders, studies of bat "Species of Concern" in upland ecosystems were added to the program in 1995 (Alice Chung-MacCoubrey, RMRS, Albuquerque), and some preliminary results have been published (Chung-MacCoubrey 1996). Because the Southwest has higher levels of species endangerment than most other areas of the United States or Canada, we deemed it critical to develop methodology for detecting population problems and solutions for recovering sensitive species. Given the influence of the Endangered Species Act on how forest, rangelands, and rivers in the

Southwest and in the middle Rio Grande Basin are managed, our faunal studies play a key role in supplying scientific information to a large and diverse group of Basin stakeholders.

Milestones and Graduate Studies

The following milestones have been achieved by the Rio Grande Program:

- 1994 Rio Grande Ecosystem Management Grant funded and chartered.
- 1995 Rio Grande Basin Assessment published and first riparian symposium hosted.
- 1996 Proceedings, desired future conditions for riparian ecosystems published.
- 1997 ARC-INFO vegetation classification maps for the Rio Grande produced.
- 1998 Symposia Rio Grande Ecosystems (RGE) hosted.
- 1999 Proceedings, RGE and Environmental History published.

Five graduate students sponsored by the Rio Grande Program have completed their theses or dissertations:

- S. Hofstad. Sediment and nutrient loss following prescribed fire in semiarid grasslands: the potential for resource impairment. M.S. thesis. UNM, Albuquerque.
- R. Calamusso. Distribution, abundance, and habitat of the Rio Grande sucker on the Carson National Forest. M.S. thesis. NMSU, Las Cruces.
- D. Potter. Spatial relationships among lightning, precipitation, and vegetative cover in watersheds of the Rio Puerco Basin. Ph.D. dissertation. UNM, Albuquerque.
- M. J. Mund-Meyerson. Arthropod abundance and composition on native and exotic trees in the middle Rio Grande riparian forest as related to avian foraging. M.S. thesis. UNM, Albuquerque.
- D. Moyer. Influence of livestock grazing and geologic setting on morphology, hydrology and nutrient retention in four southwestern riparian-stream ecosystems. M.S. thesis. UNM, Albuquerque.

Several graduate studies are continuing or have recently been initiated:

- R. Periman. Ph.D. Human influences on landscape development. UNM.
- Chung-MacCoubrey. Ph.D. Roost ecology of bat species of concern. UNM.
- H. Walker. Ph.D. Use of salt cedar by stopover migrants. UNM.
- R. Calamusso. Ph.D. Rio Grande cutthroat trout habitat use and distribution. NMSU.

Publication Output

Over 130 publications, including journal articles, general technical reports, and symposium proceedings, have been produced since the inception of the Rio Grande program. Over half of the program's publication output between October 1995 and September 1998 was accomplished through cooperative agreements between RMRS scientists and collaborators from universities or other institutions (fig. 1). Extramural research through contracts and research joint ventures have also contributed importantly to the productivity of the program. No permanent RMRS scientists are currently assigned to the Rio Grande program, but two RMRS postdoctoral scientists (Sam Loftin and Jeff Kelly) were hired by the Rio Grande Program and have published papers in the Research Work Unit (RWU) category.

Annual output of program publications has varied somewhat by year (fig. 2). High productivity in 1996 corresponds to the issuance of the proceedings of the 1995 symposium, *Desired Future conditions for Southwestern riparian ecosystems: Bringing interests and concerns together* (Shaw and Finch 1996), sponsored by RMRS, Region 3 of the U.S. Forest Service, and the New Mexico Riparian Council. With the publication of the proceedings of the Rio Grande Ecosystems symposium, the year 1999 is well on its way to being very productive (fig. 2).

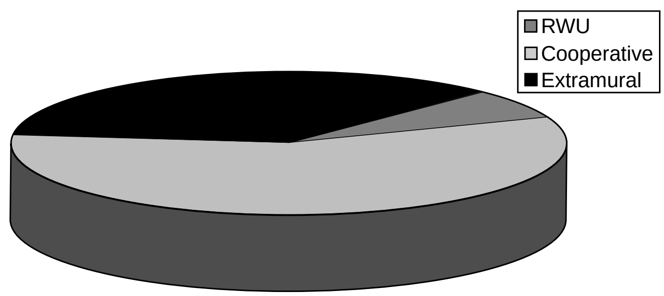


Figure 1—Percent of total research publications (1995-1998, N = 103) by output category—Research Work Unit (RWU), cooperative, and extramural—for the Rio Grande Ecosystem Management Program.

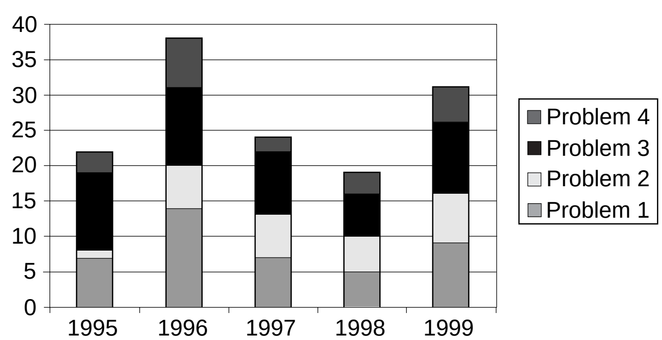


Figure 2—Total number of Rio Grande program publications (N = 134) through July 1999 by year and problem area. The total count for 1999 is incomplete. Problem 1 = underlanding upland ecosystems; Problem 2 = understanding watersheds and rivers; Problem 3 = understanding riparian ecosystems; and Problem 4 = understanding cultural dimensions.

Emerging Priorities

The Rio Grande program is responsive to changes in research priorities over time. Team members convened in July 1998 to review status of the program and identify new directions. Emerging research priorities in the Basin based on input from federal, state, municipal and private interests include:

- Understanding the influence of exotic plant invasion on ecosystem health.
- Determining methods for conserving and recovering threatened and endangered fish and wildlife species.
- Developing methods for restoring water, native plants, wildlife and proper functioning condition to rivers and watersheds.
- Understanding ecosystem dynamics in the urban-wildland interface.
- Understanding long-term human influences on riparian ecosystems of the Rio Grande.
- Developing conflict-resolution techniques to bridge gaps between environmental groups and traditional land users.
- Studying growing conflicts over species protection issues and rural economic uses and needs.

Acknowledgments

I am grateful to all cooperators, too numerous to name, in the Rio Grande program. In particular, I would like to acknowledge postdoctoral scientists Jeff Kelly and Sam Loftin for their assistance over the years in administering various nuts and bolts of the program.

References

Baisan, C.H.; Swetnam, T.W. 1997. Interactions of fire regimes and land use in the Central Rio Grande Valley. Res. Pap. RM-RP-330. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 20 p.

Calamusso, B.; Rinne, J.N. 1999. Native montane fishes of the Middle Rio Grande Ecosystem: Status, threats, and conservation. In: Finch, D.M.; Whitney, J.C.; Kelly, J.F.; Loftin, S.R., tech. coords. Rio Grande ecosystems: linking land, water, and people: toward a sustainable future for the Middle Rio Grande basin: 2-5 June 1998; Albuquerque, New Mexico. Proc. RMRS-P-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 231-237.

Chung-MacCoubrey, A.L. 1996. Bat species composition and roost use in pinyon-juniper woodlands of New Mexico. In: Barclay, R.M.R.; Bringham, R.M., eds. Bats and Forests Symposium. 19-21 October 1995; Victoria, B.C, Canada. Working Paper. WP23/1996. Victoria, B.C., Canada: Ministry of Forests, Research Branch: 118-123.

Finch, D.M.; Tainter, J.A., eds. 1995. Ecology, diversity, and sustainability of the middle Rio Grande Basin. Gen. Tech. Rep. RM-GTR-268. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 359 p.

Finch, D.M.; Whitney, J.C.; Kelly, J.F.; Loftin, S.R., tech. coords. 1999. Rio Grande ecosystems: Linking land, water, and people: toward a sustainable future for the Middle Rio Grande basin: 2-5 June 1998; Albuquerque, New Mexico. Proc. RMRS-P-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research. 245 p.

Finch, D.M.; Kelly, J.F. 1999. Status and migration of the Southwestern willow flycatcher in New Mexico. In: Finch, D.M.; Whitney, J.C.; Kelly, J.F.; Loftin, S.R., tech. coords. Rio Grande ecosystems: linking land, water, and people: toward a sustainable future for the Middle Rio Grande basin: 2-5 June 1998; Albuquerque, New Mexico. Proc. RMRS-P-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 197-203.

Kelly, J.F.; Smith, R.; Finch, D.M.; Moore, F.R.; Yong, W. 1999. Influence of summer biogeography on wood warbler stopover abundance. Condor. 76-85.

Kieft, T.L.; White, C.S.; Loftin, S.R.; Aguilar, R.; Craig, J.A.; Skarr, D.A. 1998. Temporal dynamics in soil carbon and nitrogen resources at a grassland-shrubland ecotone. Ecology. 79: 671-683.

Johnson, A.R.; Milne, B.T.; Hraber, P. 1999. Analysis of change in pinon-juniper woodlands based on aerial photography, 1930's-1980's. In: Finch, D.M.; Whitney, J.C.; Kelly, J.F.; Loftin, S.R., tech. coords. Rio Grande ecosystems: linking land, water, and people: toward a sustainable future for the Middle Rio Grande basin: 2-5 June 1998; Albuquerque, New Mexico. Proc. RMRS-P-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 106-111.

Ladyman, J.A.R.; Muldavin, E. 1996. Terrestrial cryptogamus of pinyon-juniper woodlands in the southwestern United States: A review. Gen. Tech. Rep. RM-GTR-280. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Experiment Station. 33 p.

Loftin, S.R. 1999. Trial by fire: Restoration of Middle Rio Grande upland ecosystems. In: Finch, D.M.; Whitney, J.C.; Kelly, J.F.; Loftin, S.R., tech. coords. Rio Grande ecosystems: linking land, water, and people: toward a sustainable future for the Middle Rio Grande basin: 2-5 June 1998; Albuquerque, New Mexico. Proc. RMRS-P-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 119-122.

Moyer, D.L.; Dahm, C.N.; Valett, M.H.; Thibault, J.R.; Marshall, M.C. 1998. Effects of livestock grazing on morphology, hydrology, and nutrient retention in four southwestern stream ecosystems. American Water Resources Association. TPS-98-1: 397-408.

Pawelek, D.; Jemison, R.; Neary, D. 1999. A constructed wet meadow model for forested lands in the Southwest. In: Finch, D.M.; Whitney, J.C.; Kelly, J.F.; Loftin, S.R., tech. coords. Rio Grande ecosystems: linking land, water, and people: toward a sustainable future for the Middle Rio Grande basin: 2-5 June 1998; Albuquerque, New Mexico. Proc. RMRS-P-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 97-98.

Periman, R.D. 1999. Dynamic human landscapes of the Rio del Oso: Restoration and the simulation of past ecological conditions in the Upper Rio Grande Basin. In: Finch, D.M.; Whitney, J.C.; Kelly, J.F.; Loftin, S.R., tech. coords. Rio Grande ecosystems: linking land, water, and people: toward a sustainable future for the Middle Rio Grande basin: 2-5 June 1998; Albuquerque, New Mexico. Proc. RMRS-P-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 12-19.

Potter, D.U.; Gosz, J.R.; Molles, M.C., Jr.; Scuderi, L.A. 1998. Lightning, precipitation and vegetation at landscape scale. Landscape Ecology. 13: 203-214.

Raish, C. 1998. Agricultural intensification and the economic role of domesticated animals. Papers and Proceedings of the Applied Geography Conference. 21: 137-147.

Raish, C. 1999. Espanola/Canjilon pilot study: Economic, social, and cultural aspects of public land grazing on the Santa Fe and Carson National Forests. In: Finch, D.M.; Whitney, J.C.; Kelly, J.F.; Loftin, S.R., tech. coords. Rio Grande ecosystems: linking land, water, and people: toward a sustainable future for the Middle Rio Grande basin: 2-5 June 1998; Albuquerque, New Mexico. Proc. RMRS-P-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 35-38.

Schweitzer, S.H.; Finch, D.M.; Leslie, D.M., Jr. 1998. The brown-headed cowbird and its riparian-dependent hosts in New Mexico. Gen. Tech. Rep. RMRS-GTR-1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 23 p.

Scurlock, D. 1998. From the Rio to the Sierra: An environmental history of the middle Rio Grande Basin. Gen. Tech. Rep. RM-GTR-5. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 440 p.

Shaw, D.W.; Finch, D.M., tech. coords. 1996. Desired future conditions for Southwestern riparian ecosystems: Bringing interests and concerns together. 18-22 September 1995; Albuquerque, NM. Gen. Tech. Rep. RM-GTR-272. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Experiment Station. 359 p.

Swetnam, T.W.; Betancourt, J.L. 1999. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. Journal of Climate. 11: 3128-3147.

Valett, H.M.; Dahm, C.N.; Campana, M.E.; Morrice, J.A.; Baker, M.A.; Fellows, C.S. 1998. Hydrologic influences on groundwater-surface water ecotones: Heterogeneity in nutrient composition and retention. Journal of North American Benthological Society. 16: 239-247.

White, C.S.; Loftin, S.R.; Aguilar, R. 1997. Application of biosolids to degraded semiarid rangeland: nine-year responses. Journal of Environmental Quality. 26: 1663-1671.

White, C.S.; Dreesen, D.R.; Loftin, S.R. 1998. Cobble mulch: An Anasazi water-conservation gardening technique. In Klett, C.T.O., ed. 42nd Annual New Mexico Water Conference Proceedings. 2-3 October 1997; Las Cruces, NM. WRRI Report 304. Las Cruces, NM: New Mexico Water Resources Research Institute: 109-121.

White, C.S.; Loftin, S.R.; Hofstad, S. 1999. Response of vegetation, soil nitrogen, and sediment transport to a prescribed fire in semiarid grasslands. In: Finch, D.M.; Whitney, J.C.; Kelly, J.F.; Loftin, S.R., tech. coords. Rio Grande ecosystems: linking land, water, and people: toward a sustainable future for the Middle Rio Grande basin: 2-5 June 1998; Albuquerque, New Mexico. Proc. RMRS-P-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 83-92.

Wozniak, F.E. 1998. Irrigation in the Rio Grande Valley, New Mexico: A study and annotated bibliography of the development of irrigation systems. Proc. RMRS-P-2. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 204 p.

Yong, W.; Finch, D.M. 1997a. Population trends of migratory landbirds along the middle Rio Grande. Southwestern Naturalist. 42: 137-147.

Yong, W.; Finch, D.M. 1997b. Migration of the willow flycatcher along the middle Rio Grande. Wilson Bulletin. 109: 253-268.

Yong, W.; Finch, D.M.; Moore, F.R.; Kelly, J.F. 1998. Stopover ecology and habitat use of migratory Wilson's Warblers. Auk. 115: 829-842.

The Colorado Front Range Ecosystem Management Research Project: Accomplishments to Date

Brian Kent
Wayne D. Shepperd
Deborah J. Shields

Abstract—This article briefly describes the goals and objectives for the Colorado Front Range Ecosystem Management Project (FREM). Research under this project has addressed both biophysical and human dimensions problems relating to ecosystem management in the Colorado Front Range. Results of completed work are described, and the status of the ongoing demonstration project at Manitou Experimental Forest is given.

The Colorado Front Range Ecosystem Management (FREM) project was initially funded in FY 1994 to address issues related to ecosystem management (EM) in an area (fig. 1) of rapidly growing human populations, complex and sensitive ecosystems, and diverse social and economic systems. The original proposal contained six objectives, but because of limited funding, only three were addressed:

1. Integrate social, organizational, and ecological values and issues, and improve conflict management strategies and tradeoff analysis techniques to support land management planning.
2. Improve our understanding of key biological and physical aspects of ecological systems and the interactions of humans on ecosystem structure, diversity, and productivity.
3. Initiate operation of a learning center to facilitate information sharing and to support the building of active partnerships.

The following three areas were selected for primary focus: improve understanding of a key Front Range ecosystem, develop collaboration strategies, and instigate stakeholder education. FREM team members chose a two pronged approach for ensuing work: (1) identify and collect the types of information needed about one important ecological system (ponderosa pine, *Pinus ponderosa*) and how it responds to human impacts, and (2) develop approaches to involving stakeholder groups and other interested parties in resource management decisions. Results from this work are being used to design and implement an education and demonstration study on the Manitou Experimental Forest, located in the ponderosa pine type.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Brian Kent is Project Leader, Wayne D. Shepperd is Research Forester, and Deborah J. Shields is Principal Minerals Economist, Rocky Mountain Research Station, Fort Collins, CO 805267, e-mail: bkent@fs.fed.us AND wshepperd@fs.fed.us AND dshields@fs.fed.us

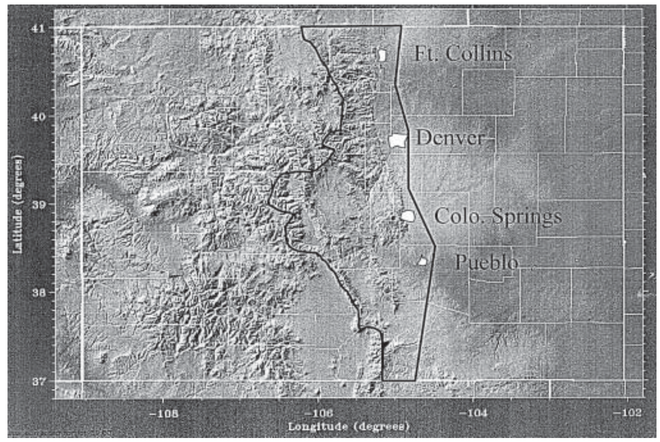


Figure 1—The area encompassed by the Front Range Ecosystem Management Research Project includes all mountainous lands in the South Platte and Arkansas River drainages.

Biophysical Research

Like much of the Interior West, the Colorado Front Range has been profoundly altered by fire suppression management strategies over the past 100 years or so. Photographic records suggest this to be the case, but prior to studies undertaken in ponderosa pine stands as part of FREM, actual fire histories for sites along the Front Range had never been developed. Generally, results show that the normal pattern prior to European settlement was one of relatively frequent, usually low intensity fires, as the chronology for the Manitou Experimental Forest (MEF) (fig. 2) shows. This result, again, is consistent with findings elsewhere in the Interior West. Fire history records have also been developed for the entire Denver Water Board Cheeseman Reservoir property (Brown and others 1999), extending back into the 1200's. These data complement overstory structure and understory biodiversity data collected in other studies and are being used to help interpret how these variables and natural and human disturbances in the ponderosa pine type are interrelated. The results of these studies will lead to better assessments of the condition of human-impacted ecosystems along the Front Range and, hence, to possible restoration recommendations for these systems.

Other FREM studies have looked at patterns of cohort distribution and gap dynamics in logged and unlogged old-growth ponderosa stands in the southern Front Range. In

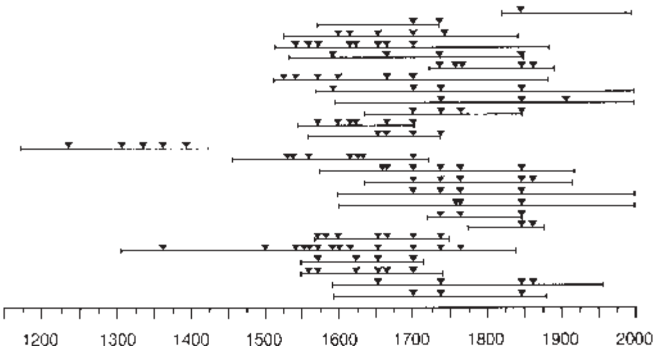


Figure 2—Fire chronology for Manitou Experimental Forest, Colorado. Lines are time spans of individual tree and wood samples. Inverted triangles record dates of fire scars in each ring series.

general, logged stands tended to be more homogeneous than old-growth stands, with higher tree density, fewer openings, and regeneration tending to occur more uniformly over time. The structurally more complex old-growth stands contained many trees of 400+ years of age. These results indicate that restoration of logged stands is possible by removing excess stocking, while existing old-growth stands can be maintained with prescribed fire and diverse management.

Like much of the Interior West, The Colorado Front Range contains extensive areas of urban-wildland interface, with much of this area being in the ponderosa pine type. These forests, like most of the rest of the Front Range, have developed in the absence of fire, and FREM studies have looked at how these stands have evolved by (1) accurately dating ponderosa pine seedlings and saplings of various sizes to their year of origin, (2) constructing a height growth model for ponderosa pine seedlings from seedling establishment to breast height, and (3) investigating temporal and spatial patterns of tree recruitment within and between groups of overstory trees. The results of this research are crucial to planning management activities to reduce fire and disease risks in these interface forests. These results are also being used in developing prescriptions for the cooperative demonstration project underway at MEF.

Improved knowledge about the seedling establishment of ponderosa pine is essential to developing effective prescriptions for restoring stands to more fire resistant status. Results from earlier studies suggest that seedlings are spatially distributed as a direct consequence of seed availability, or proximity to overstory trees, and of microenvironmental conditions during the summer growing season. FREM studies are testing these hypotheses, and the results are being applied to the demonstration project.

The Hierarchical Model of Collaborative Ecosystem Management

The Hierarchical Model of Collaborative Resource Management (HM) is one of the primary products of FREM. It is a model that explicitly incorporates the interests and desires of the public in the EM decisionmaking process. In the HM, decisions about how resources are managed follow as a consequence of societal values in general and those associated with nature in particular. Societal values, and related objectives for natural resources, translate into alternative management actions. It is possible to estimate the consequences of implementing an alternative by forecasting the status of measures or indicators of current and projected environmental, social, and economic system condition. Moreover, since the measures are linked directly to the objectives, information is also available on the potential consequences of fulfilling specific objectives. Thus, the HM takes the form of a complex systems problem, i.e., one that is hierarchical and ordered and embodies control and information flows.

The Design of the Hierarchical Model

The HM design is based on (1) the pragmatic view that resource management is, by definition, a human action, motivated by human desires, and (2) the principle that resource management goals make sense only within the context of the human social system (Cooper 1969). The philosophical perspective is anthropogenic. All values, including those dealing with the environment, are human derived (Santayana 1896); however, humans are capable of finding value in nature (Brown and Peterson 1994; Rolston 1994). Ultimately, human values drive the environmental and resource goal setting processes that inform EM decisionmaking. This perspective allows for a comprehensive conception of human well-being, one that embraces what might otherwise be thought of as irrational, e.g., non-self motivated, behaviors and choices. Thus, the survival of species and the needs of future generations, in addition to a desire for jobs, income and commodities, become legitimate concerns, and in the process influence decisions and actions.

Consistent with the above view, basic human values (sometimes called held values) are placed over the cultural, institutional, and economic framework within which societal goals and objectives are communicated, over assigned value measures, and over the actions that can impact the biophysical system (fig. 3). Typical of hierarchies, control flows from the top to the bottom; information flows in the opposite direction. Basic held values are assumed to determine the social objectives that drive land management decisions. Implementation of these decisions leads to biophysical and social impacts and, in a fully functioning application of this model, information about those impacts would be passed back up through the levels of the hierarchy.

A held value can be defined as "an enduring conception of the preferable which influences choice and action" (Brown 1984). They comprise highest-order qualities that motivate all ensuing lower-order preferences and, consequently, decisions and actions. Examples include generosity, responsibility, fairness, freedom, etc. (Brown 1984). Each person has his/her own set of held values; the sets are not necessarily identical, although they may overlap. Individuals tend to have relatively few held values (perhaps 10 or 15 at most) and also tend to order them, i.e., certain values are given precedence and emphasis over others (Boulding and Lundstedt 1988). Held values are extremely resistant to change without immense outside perturbation. In less extreme situations, existing values may be given increased or

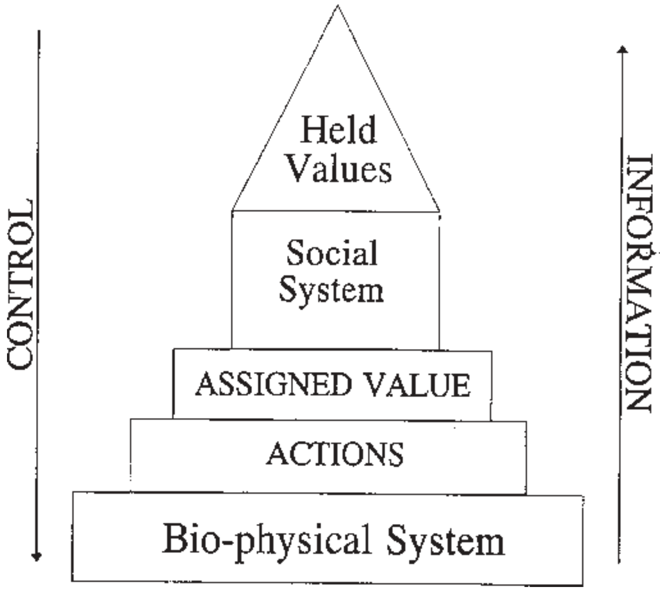


Figure 3—Schematic of a hierarchical model for collaborative resource management.

decreased emphasis, to be shifted to a higher or lower place in the overall value hierarchy (Rescher 1969). It is possible to identify held values through psychometric tests or carefully worded survey instruments (Hetherington and others 1994).

The social system and its related institutions evolve out of held values and are ranked below them in the HM. Social values are derived from held values; together they provide the ethical foundation for social institutions and the rationale for governmental, corporate, and individual decisions. Societies hold social values with regard to equity before the law, economic justice, and the environment, plus other values less relevant in a resource context. Environmental values are the source of the strategic objectives people hold for natural resources and so have been of particular interest to those concerned with resource management decisionmaking (Bengston 1994).

The public policy decision process is one in which held values, beliefs, and knowledge inform a cognitive valuation process that results in the assigning of relative value to alternative policies or states of the world (Stoll and Gregory 1988). In the HM, the primary connections from society to the biophysical system are through this intervening level of assigned values. Decisionmakers choose from among alternative actions, based on a comparison of their relative values. One problem has been that decision makers have historically relied too heavily on monetized values as a way to compare resource management alternatives. EM decision processes can benefit from the addition of information on how implementation of various alternatives would affect different stakeholder's perceptions of their own well-being. Assuming rationality, individuals make choices so as to maximize their well-being. Preferences, which are derived from objectives, drive the alternative comparison process. There is general agreement that people's objectives and preferences for specific resource management schemes are a function of their value sets (Steel and others 1994).

Implementation of each management action will result in a set of impacts on the social, economic and environmental systems in question. The HM accounts for the flow of information regarding the effects of alternative choices to stakeholders, be they land managers or members of the general public. Impacts can be predicted for each proposed action and changes in system condition estimated. Comparisons across alternatives can be made, and these are useful because they help both agencies and members of the public understand the short- and long-term consequences of implementing various management alternatives. In some instances, understanding the broader implications of a decision may lead to a change in the value assigned to a specific activity or situation. This in turn could lead to a reprioritization of objectives, which might imply that a different choice would be made. The ability to facilitate learning and adaptation through the upward flow of relevant information is one of the most important features of the HM, and makes it a useful construct in an adaptive management setting.

Quantifying the Hierarchical Model

The HM is a theoretical construct that hypothesizes a relationship among values, social institutions, assigned values, personal or agency actions, and their associated environmental impacts. Although the construct is realistic, it cannot be applied directly to resource management problems in the absence of practical quantitative tools. To bridge the gap between theory and the reality of management decisionmaking, two alternative implementation approaches have been developed. The first of these, the measurement model, investigates the pathway from values to actions and behaviors. The second, the preference model, uses a decision theoretic approach to link objectives to assigned values (preferences) and thus to choices among alternative actions. The relationship between the HM and the two models is shown in figure 4.

The Measurement Model—The measurement model provides a means for linking values to behaviors and has been derived from the traditional values-attitudes-behaviors framework widely accepted in social psychology and consumer behavior literature (Homer and Kahle 1988). Those models omit objectives; however, most behavior is, in reality, goal directed (Huffman and Houston 1993). Thus, the framework has been modified to incorporate objectives, which have been demonstrated to mediate the relationship between values and attitudes in a FREM funded study (Martin and others 1998). This leads to a values-objectives-attitudes-behaviors (VOAB) construct.

The measurement model mirrors the HM. Thus, the uppermost level is values. The focus is on environmental values, and these are assumed to provide the motivation for objectives, attitude formation and behavior. Objectives reside at the second level of the measurement model, and they reflect, and are tempered by, the existing social, institutional, and cultural milieu within which an individual lives, in addition to being derived from the individual's value set. This model does not specifically incorporate assigned values, but rather their precursor, attitudes. Actions are represented by behaviors, which can take the form of personal

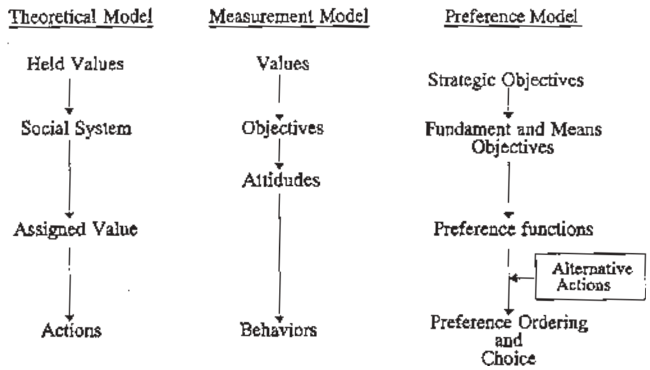


Figure 4—Flowchart comparing components of the measurement, and preference model alternative implementation approaches to those of the theoretical hierarchical model for collaborative resource management.

behaviors or, at the agency level, management decisions. The actions represent tangible evidence of attitudes.

As part of FREM, a survey instrument design has been developed to elicit information from individuals about their values, objectives attitudes, and behaviors with respect to natural resources (Martin and others 1998). Survey results can be explored using descriptive statistics, cluster analysis, and structural equation models (Martin and others 1997).

The Preference Model—The preference model provides a means for linking objectives for natural resource management to choices among potential implementation strategies. The approach is based on decision theoretic methods that are widely used to evaluate alternatives involving multiple objectives (Keeney and Raiffa 1976; von Winterfeldt and Edwards 1986). As shown in figure 4, this approach follows a path from strategic objectives to fundamental and means objectives, to preference functions, ending with preference ordering and choice.

The path parallels the measurement model, but differs from it in a number of significant ways. First, values are not explicitly addressed, but rather are assumed to be the basis for strategic objectives. Second, objectives are quantified in preference functions, which become, then, situation specific applications of values. They quantify stakeholder objectives with regard to each alternative action in terms of a relevant set of indices or measures of social, economic and ecosystem condition. Third, given that alternative actions will generate difference indicator or measure levels, it is possible to calculate a score for each action by solving the preference functions for the relevant measures data.

Because relative scores and hence, rankings, can be assigned to each alternative for each stakeholder, this information can be used to help develop consensus over which one to select. Unfortunately, no failure proof method of choosing among alternatives exists that is acceptable in democratic society. However, assuming that all relevant points of view and conflicting interests are adequately represented, a choice that provides a socially acceptable tradeoff among these interests could be considered satisfactory. To accomplish this, processes of individual and group choice can be investigated by using the scores as inputs to voting, game theoretic and equity models. Two FREM funded studies that have applied these techniques to ecosystem management problems are Shields and others (1999), using game theory, and Martin and others (1996), using voting models.

Value-Based Decisionmaking Versus Alternative-Based Decisionmaking

Values have long been recognized as a means to better understand society and culture, based on the premise that they play an important role in human behavior. It is clear from the above description of the HM that it is a values-based construct, and as such, it is an example of what Keeney (1992) calls “value-focused thinking.” However, conventional decisionmaking approaches usually revolve around the generation and evaluation of alternatives, which Keeney refers to as “alternative-focused thinking.” If we view values as characterizations of what we care about in a given decision situation, they are of obvious fundamental importance, clearly more so than alternatives. In a value-focused approach, alternatives are viewed as mechanisms to achieve values. This does not mean that alternatives are not important; in fact, one of the strengths of a value-based approach is that it can facilitate the development of a richer set of alternatives by first identifying what is important (values) and then using this information to craft alternatives.

To date, most contentious resource decision situations in the Forest Service involving external stakeholders have been conducted in an environment of alternative-focused thinking. However, within FREM, three studies are underway that consider stakeholder objectives (which arise directly from values) as they apply to Forest Service decision situations on the Colorado Front Range. They focus on developing tools for eliciting information about the resource related goals and objectives of public land stakeholders and linking those goals to measurable attributes of community and ecosystem status and trend. The goals and objectives information is being considered within the context of its relationship to stakeholders’ held values, their attitudes about activities taking place on public lands, and their personal behavior on these lands. The National Forests involved are the San Juan (Martin and others, in press), the Pike/San Isabel, and the Arapaho/Roosevelt.

Values, Objectives, and Objectives Hierarchies

As noted above, values are not explicitly expressed in the measurement model and the preference model of the Hierarchical Model, but rather are assumed to be the basis for strategic objectives. This is consistent with the idea that prevailing community objectives generally make up basic conditions for achieving legitimate land use policy (Caldwell 1990). This is a primary reason why stakeholder involvement is essential to effective EM, and why both the measurement and preference models are designed to incorporate stakeholder group and individual objectives (fig. 4). An objective is a statement of what one desires to achieve and is characterized by having a context (in this instance, natural resources), an object (an action alternative) and a direction of preference (Keeney 1992). By comparing objectives (i.e., across individuals, firms, agencies), it is possible to identify those that are held in common and those that are unique to special interests. Often significant overlap among objectives sets exists, which presents opportunities for consensus building among stakeholders.

Information on objectives can be organized into an objectives hierarchy, which is a tree-like representation of an individual's or group's objectives (Caldwell 1990; Keeney and Raiffa 1976). Space does not permit a detailed description of an objectives hierarchy, but the levels are the same as shown in figure 4 for the preference model because objectives hierarchies are integral to that model. The points here are that objectives are the key component of the preference model and are an important component of the measurement model because they provide the link back to values that is necessary to make these models examples of value-focused thinking. Objectives hierarchies have been built for many public policy applications (Keeney 1988; Keeney and others 1990), and are an important component of the FREM human dimension studies mentioned above.

Figure 5—Aerial view of layout of the 25 ha Manitou Experimental Forest Demonstration Project. Treated areas are being harvested under an irregular uneven-aged management scheme. Post-treatment response will be compared to that of the adjoining control area.

The Front Range Demonstration Project

This project is a demonstration of management techniques applicable in Front Range urban-interface ponderosa pine forests, designed to bring together results from both the biophysical and human dimensions work described above. The primary objective of this project is to conduct an on-the-ground test of management techniques that can be used to improve the health of Front Range ponderosa pine forests by reducing the risks of fire and other catastrophic disturbances, such as bark beetle (*Dendroctonus* spp.) infestation, in a manner acceptable to human desires and perceptions of these ecosystems. It has been established on the Manitou Experimental Forest in cooperation with the Pike San Isabel National Forest, Region 2, the Bureau of Land Management and the Colorado State Forest Service. Other objectives include:

1. Establish a facility that can be used to interpret and contrast forest conditions and assess the benefits/tradeoffs of ecosystem management at a single, easily accessible site,
2. Provide a database and opportunity for long-term monitoring of forest health and management activities in a Front Range forest,
3. Utilize the objectives hierarchy process, and the associated survey instrument, to ascertain public perceptions about specific treatments, and
4. Perform experiments utilizing a structural equations model to determine the impact on public values-objectives-attitudes-behaviors of information presented in different formats.

Study Description

A 25 ha forested site near the MEF headquarters was chosen for the demonstration (fig. 5). Readily accessible to the public, the site consists of a series of small drainages that are populated with a structurally diverse ponderosa pine stand that has developed after logging in the late 1800's. Small portions of the site were harvested in the late 1940's as part of the early watershed experiments at MEF, but the remainder of the site has remained undisturbed by man during the 20th century.

Fire-scarred trees, stumps, and burned logs indicate a history of past fires on the site. A stand in the eastern portion of the site is heavily impacted by mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) and has suffered heavy mortality. Few dead trees or logs exist throughout the rest of the site, indicating that no other insect or disease outbreaks have occurred. A stand in the western portion of the site is more open and contains some seedlings and saplings, but little regeneration exists elsewhere.

Site Layout/Pretreatment Data Collection—The site will be used to compare a no treatment control against a prescribed fire treatment, an uneven-aged silvicultural treatment, and a combination of silvicultural treatment followed by fire—all designed to maintain the health and vigor of this site. Layout and pre-treatment data were completed in 1997, and the treatment sale was marked and sold in 1998. Plans are to harvest the sale in 1999 and begin subsequent monitoring following treatment.

Pre-treatment data collection include the surveying and installation of a grid of permanently marked reference points at 100 m intervals throughout the site to be used by researchers working in the area. A series of inventory plots describing the species composition, size, age, and density of the forest throughout the area were established on these grid points in 1997. Extensive tree ring data was collected to describe present and past forest structure and development. Fire scar data was collected from living trees and dead material in the area, and a complete fire history was developed for the demonstration site (fig. 2).

Preliminary focus group interviews for stakeholder groups interested in the MEF are being conducted this summer and fall. Relevant statistical analyses will be completed this winter, and the results will be used to design the VOAB survey and to develop the objectives hierarchy needed to develop the measurement and preference models needed to apply and quantify the HM to this demonstration study.

References

Bengston, D.S. 1994. Changing forest values and ecosystem management. Society and Natural Resources. 7: 515-533.

Boulding, K.E.; Lundstedt, S.B. 1988. Value concepts and justifications. In: Peterson, G.L.; Driver, B.L.; Gregory, R., eds. Amenity resource valuation. State College, PA: Venture Publishing Company: 13-22.

Brown, P.M.; Kaufmann, M.R.; Shepperd, W.D. 1999. Long-term landscape patterns of past fire events in a montane ponderosa pine forest of central Colorado. Landscape Ecology. 14: 513-532.

Brown, T.C.; Peterson, G.L. 1994. A political-economic perspective on sustained ecosystem management. In: Debano, L.F., ed. Sustainable ecological systems: implementing an ecological approach to land management. Gen. Tech. Rep. RM-247. Fort Collins CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 228-235.

Brown, T.C. 1984. The concept of value in resource allocation. Land Economics. 60: 231-246.

Caldwell, L.K. 1990. Landscape law and public policy: conditions for an ecological perspective. Landscape Ecology. 5: 3-8.

Cooper, C.F. 1969. Ecosystem models in watershed management. In: Van Dyne, G.M., ed. The ecosystem concept in natural resource management. New York, NY: Academic Press: 309-324.

Hetherington, J.; Daniel, T.C.; Brown, T.C. 1994. Anything goes means everything stays: the perils of uncritical pluralism in the study of ecosystem values. Society and Natural Resources. 7: 535-546.

Homer, P.M.; Kahle, L.R. 1988. A structural equation test of the value-attitude-behavior Hierarchy. Journal of Personality and Social Psychology. 54: 638-646.

Huffman, C.; Houston, M. 1993. Goal-oriented experiences in the development of knowledge. Journal of Consumer Research. 20: 190-207.

Keeney, R.L. 1992. Value-focused thinking. Cambridge, MA: Harvard Univ. Press. 415 p.

Keeney, R.L.; von Winterfeldt, D.; Eppel, T. 1990. Eliciting public values for complex policy decisions. Management Science. 36: 1011-1030.

Keeney, R.L. 1988. Structuring objectives for problems of public interest. Operations Research. 36: 396-405.

Keeney, R.L.; Raiffa, H. 1976. Decisions with multiple objectives. New York, NY: Wiley and Sons. 569 p.

Martin, I.M.; Bender, H.W.; Martin, W.E.; Shields, D.J. 1997. The development of a values scale: consumption of public lands. Golden, CO: Colorado School of Mines, Division of Economics and Business. Working Paper. 29 p.

Martin, W.; Shields, D.J.; Tolwinski, B.; Kent, B. 1996. An application of social choice theory to USDA Forest Service decisionmaking. Journal of Policy Modeling. 18: 603-621.

Martin, I.M.; Bender, H.W.; Martin, W.E.; Shields, D.J. 1998. The impact of goals on the “values-attitudes-behaviors” framework. Decision Sciences Institute Proceedings. Vol. 1: 126-129.

Martin, W.E.; Shields, D.J.; Wise, H.A. [In press]. Stakeholder objectives for public lands: ranking of forest management alternatives. Journal of Environmental Management.

Rescher, N. 1969. Introduction to value theory. Englewood Cliffs, NJ: Prentice Hall. 191 p.

Rolston, H., III. 1994. Conserving natural value. New York, NY: Columbia University Press. 259 p.

Santayana, G. 1896. The sense of beauty. New York, NY: Scribner’s and Sons. 275 p.

Shields, D.J.; Tolwinski, B.; Kent, B. 1999. Models for conflict resolution in ecosystem management. Socio-Economic Planning Sciences. 33: 61-84.

Steel, B.S.; List, P.; Schindler, B. 1994. Conflicting values about federal forests: a comparison of national and Oregon publics. Society and Natural Resources. 7: 137-153.

Stoll, J. R.; Gregory, R. 1988. Overview. In: Peterson, G.L.; Driver, B.L.; Gregory, R., eds. Amenity resource valuation. State College, PA: Venture Publishing Co: 3-6.

von Winterfeldt, D.; Edwards, W. 1986. Decision analysis and behaviorial research. Cambridge, England: Cambridge University Press. 604 p.

Sustaining the Land, People, and Economy of the Blue Mountains: The Blue Mountains Natural Resources Institute

Lynn Starr
James McIver
Thomas M. Quigley

Abstract—The Blue Mountains Natural Resources Institute approaches issues by deciding if a critical issue is one of information needs or of differing values. If a values issue, we arrange local forums for discussion; if an information issue, we disseminate available information, or undertake research projects as appropriate. One issue we have researched involving both values and information needs is fuel reduction. Through an adaptive management cycle of treatment, evaluation, and refinement, we have brought new understanding to management options for fuel treatment efforts and the ecological and economic results. A survey on acceptance of fuel reduction methods allowed integration of social, ecological, and economic factors, an essential feature of ecosystem management.

The Blue Mountains Natural Resources Institute was formed in 1990 in response to a grassroots effort by several committed local citizens in northeastern Oregon and southeastern Washington concerned about declining forest conditions. Eighty years of fire suppression and preferential harvest of old-growth ponderosa pine (*Pinus ponderosa*) had created a landscape with many overstocked stands and large accumulations of fuel. Drought during the 1980s and conspicuous outbreaks of insect pests fueled concern that the Blue Mountains were ripe for uncharacteristically severe wildfire. Citizens wanted research to focus on the problem to provide land managers with ways to reduce risks. The citizen effort to create the Institute was assisted by the Forest Service Pacific Northwest Research Station to draft the Institute charter, mission, and goals. Through citizen efforts, the Institute was mandated by the Food, Agriculture, Conservation, and Trade Act of 1990 and chartered as a Federal Advisory Committee. The committee took the form of a Board of Directors representing a variety of groups interested in natural resources: Federal and state agencies, universities, industry, private landowners, environmental advocates, tribes, and county governments. The Institute was designed to have no authority over management, but to offer information focused on finding ways to improve forest conditions.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Lynn Starr is Acting Manager, Blue Mountains Natural Resources Institute, James McIver is the Research Coordinator, and Thomas M. Quigley is the Program Manager, Managing Disturbance Regimes, USDA Forest Service, Pacific Northwest Research Station, 1401 Gekeler Lane, La Grande, OR 97850.

The mission of the Institute is to enhance the economic and social benefits derived from the natural resources of the Blue Mountains in a manner that is ecologically sound and sustainable (Tanaka and others 1993). The area served by the Institute includes four counties in southeastern Washington and all or part of ten counties in northeastern Oregon (fig. 1). We address the mission in three broad ways: forums for discussion, education/outreach, and research. Our clientele includes anyone involved with natural resources, including private landowners, agency managers, scientists, students, and interested citizens. We have formed formal partnerships with over 80 entities and involved partners in planning and executing research programs, forums, and educational efforts such as seminars, tours, conferences, and a quarterly newsletter.

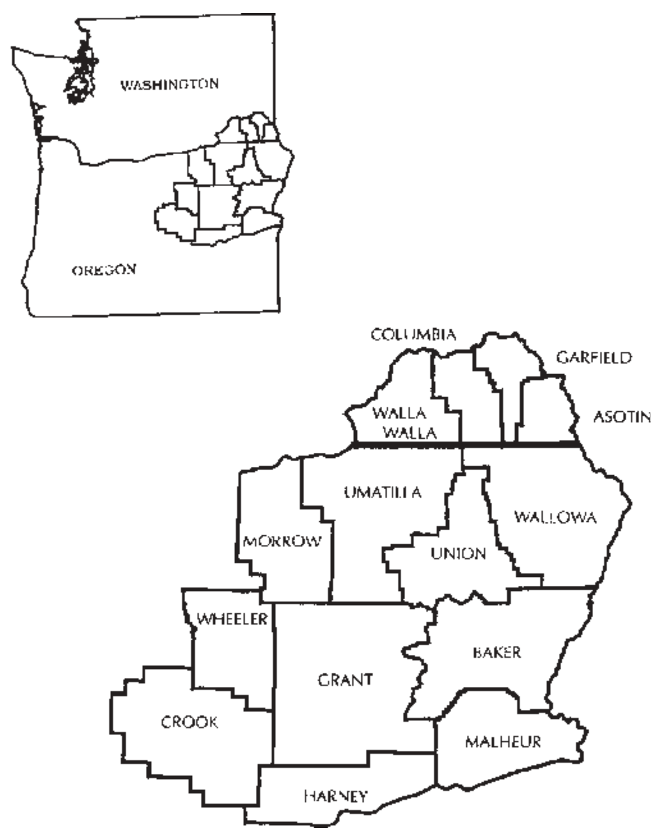


Figure 1—Area covered by the Blue Mountains Natural Resources Institute.

The Institute approach to an issue can be described as a decision chart. We first ask if a critical issue is one of knowledge or of values. If it is a values question, we approach it by organizing forums for discussion. If it is a knowledge issue, we determine if there is existing information that can be brought to bear. We collect what information is available and disseminate it through appropriate media: tours, workshops, seminars, published papers, conferences, and technical notes. If we determine that there is a knowledge gap, then we work with partners to conduct research. Our research program takes an adaptive ecosystem management approach with three main principles: a management orientation; integration of economic, social, and biological disciplines; and a technology transfer component.

In deciding where to focus our efforts, we look to the Board of Directors, our partners, and our technical committees. The Board of Directors typically identifies the main issues of concern.

Early on, the Board wanted a discussion on how people viewed forest health. In 1991 and 1992, we conducted a series of forums on forest health throughout the Blue Mountains area (Starr and Quigley 1992). At each forum, we invited representatives of an array of interests to speak on forest health from their viewpoint. The speakers were local as much as possible and included Forest Service scientists and managers, state departments of wildlife and forestry, tribes, local businesses, county government, and environmental advocates. They each gave brief presentations followed by questions and answers. It was illuminating to have people with such a wide variety of viewpoints speak at one gathering. This helped inform the public, Institute staff, Board of Directors, and the speakers as well. These forums helped the Institute build a foundation of credibility to offer unbiased information and have all viewpoints honored.

While values on forest health served as the focal issue initially, one of the first orders of business was to identify gaps in scientific knowledge across the wide spectrum of issues relating to forest conditions. Technical committees were formed to discuss research needs in each of nine issue areas such as “wildlife,” “biodiversity,” and “socioeconomic concerns.” Output from the technical committees helped to guide a literature search and synthesis of existing natural resource information on the Blue Mountains (Jaindl and Quigley 1996). This work summarized the knowledge to date and also identified the most critical research topics. We also found a need for other such synthesis efforts on more focused topics and undertook one on salvage harvest (McIver and Starr 2000).

One research topic that was identified as a knowledge gap by the technical committees was acceptable methods of fuel reduction, and we have focused considerable energy on it. Our fuel reduction work, like most of our research, has used the adaptive management model, with evaluation of a research effort leading to refinement and another focused research effort. We have been able to partner with land managers to take advantage of their operations to apply treatments, and we then measure the responses. We began by building on the Genesis Demonstration project on the Malheur National Forest. The project involved citizens in shaping plans, and then applied management practices such as thinning and prescribed fire to restore and sustain the health and productivity of the land. The research component conducted by Oregon State University (OSU) scientists examined how thinning and fire might influence the activity of forest pathogens and alter the abundance and distribution of standing and down dead wood.

Building on the Genesis Project, a team of OSU scientists evaluated fuel reduction by means of a cable yarding system on level ground coupled with a mechanical harvester (The Deerhorn Project; Kellogg and Brown 1995; McIver 1995). We wanted to see if the cable system could be used economically on level ground to reduce soil effects of fuel reduction activities. Fuels were significantly reduced at Deerhorn by cable yarding, and soil disturbance was less than that typically produced by a skidding system. Economically the operation was a narrow success, through the production of both sawlogs and chips. Effects of the fuel reduction on ants and pileated woodpecker (*Dryocopus pileatus*) foraging were also studied.

Based on findings in these earlier studies, a replicated study was designed for the Limber Jim site on the Wallowa-Whitman National Forest. Cooperators included La Grande District personnel; scientists from OSU, Pacific Northwest Research Station (PNW), and the University of California-Davis; and private contractors who purchased the materials and performed the logging to specification. Researchers compared forwarding with skyline yarding, both coupled with the single-grip harvester. Variables measured included fuel reduction, soil effects, residual tree damage, pine marten (*Martes americana*) habitat effects, and economics (Drews and others 1998; McIver 1998). These three sets of information—objective, environmental effects, and economics—integrated into one study allowed managers to make more informed decisions (fig. 2). In this case, single-grip harvesting to fell trees, coupled with forwarding to retrieve them, was the best choice in terms of both economics and environmental effects.

Yet another study in the cycle of adaptive management is under way on the Wallowa-Whitman National Forest. This

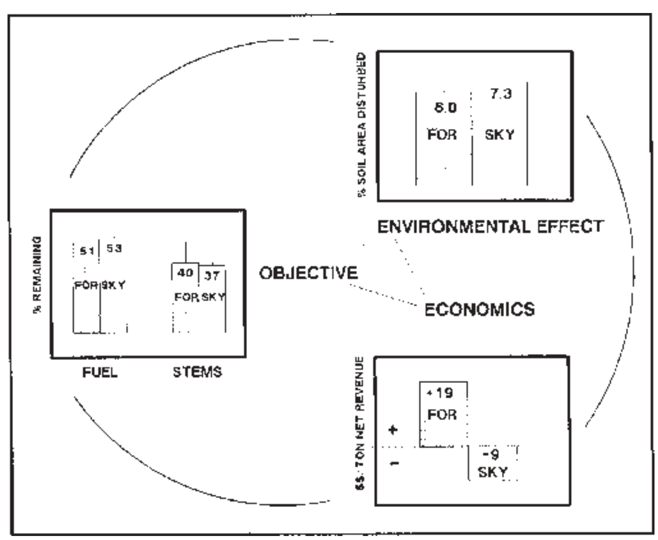


Figure 2—The three sets of information needed to make decisions on management tradeoffs: the Objective, the Environment Effects, and the Economics.

study at Hungry Bob will compare fire and thinning as methods of fuel reduction. Currently, thinning treatments have been applied, and prescribed fire is scheduled for late summer 1999. We will again employ scientists from OSU and PNW to study economics and environmental effects. Replicated treatments are prescribed fire, thinning, thinning followed by fire, and untreated control. In addition to looking at economics, soil disturbance, and residual tree damage, we will also investigate below-ground processes.

Taken together, these fuel reduction studies illustrate the use of adaptive management (fig. 3) in which action is taken, results are evaluated, and the next action is taken using modified methods based on improved knowledge. Results from research are quickly transferred to managers and the public through as many means as needed (tours, videos, brochures, technical notes), and, from this body of information, more-informed decisions are made. From Genesis to Hungry Bob, operational research conducted in an adaptive management context has provided increasing knowledge on the practice of fuel reduction. In these times, land managers are faced with intense scrutiny of their actions and imperfect knowledge on which to base their decisions. Adaptive management offers a way for managers to move ahead based on the best available knowledge, and to decrease risk and uncertainty.

It is also important to remember that the technical information generated by these studies will only be useful if the public supports the objective of fuel reduction and the methods used to accomplish it. Thus, we commissioned a survey conducted by OSU scientists to examine public acceptance of alternative fuel reduction methods (Shindler 1997). Results suggest broad support among citizens of the Blue Mountains for either prescribed fire or thinning for fuel reduction on Forest Service land, with thinning the preferred alternative. Taken together, the social, economic, and biological data on fuel reduction provides the manager with a complete package of information from which to make decisions, a central tenet of ecosystem management.

The types of studies we have undertaken—partnering science, management, and public together to achieve enhanced learning—require adjustments to traditional approaches. Managers need to adjust their plans to allow for random replication and for an untreated control. Scientists must adjust their plans to allow for many factors beyond their control including delays that sometimes interfere with uniform treatment. Contractors must adjust their plans to conform to strict protocols and the need for uniform treatment in the face of market fluctuations and other business demands. All this is possible only with willing cooperation from the many partners. Our adaptive approach to research demonstrates it is possible.

Though challenging, operational research is worth the result. Only in large, integrated studies that take into account the social, economic, and biologic factors, can we gain the information necessary to weigh trade-offs resulting from many management actions. Only armed with such information and with input from and concurrence of the public, can management proceed in the contentious atmosphere that characterizes natural resource issues today. An institution such as the Blue Mountains Natural Resources Institute is uniquely equipped to work with all the parties and bridge the gaps among the various interests to make such research/management projects a reality.

The mission of the Blue Mountains Natural Resources Institute remains a rallying point for its many partners. Though falling short on some partner expectations, the

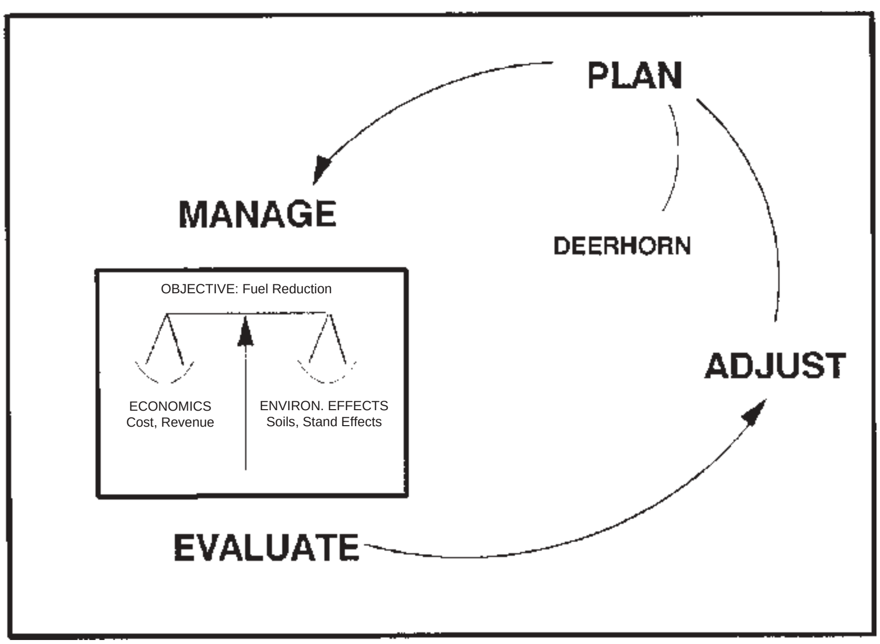


Figure 3—Adaptive management cycle using the Deerhorn-Limber Jim management experiments as sources of new information.

Institute has accomplished a wide array of successes. As the 10-year life of the Institute draws to an end, many outside factors influence its visibility. The mission is strongly supported, but downsizing and significant budget cuts in federal agencies put future funding in question. A redefined and more focused Institute may emerge. The lessons learned about partnerships, adaptive management, public understanding of technical and value issues, and integrated research will guide research and management activities well beyond the life of this single institution.

References

Drews, E.S.; Hartsough, B.R.; Doyal, J.A.; Kellogg, L.D. 1998. Comparison of forwarder cut-to-length and skyline yarder cut-to-length systems in a natural, eastern Oregon stand. In: Harvesting logistics: from woods to markets. 1998 Conference Proceedings. 20-23 July 1998; Portland, OR. Corvallis, OR: Council on Forest Engineering Conference: [pages unknown].

Jaindl, R.G.; Quiqley, T.M., eds. 1996. Search for a solution: sustaining the land, people, and economy of the Blue Mountains. Washington, D.C.: American Forests. 316 p.

Kellogg, L.D.; Brown, C.G. 1995. Using a single-grip harvester and skyline yarding system in a forest health improvement application. In: Sustainability, forest health and meeting the nation's need for wood products. 1995 Conference Proceedings. 5-8 June 1995; Cashiers, NC. Corvallis, OR: Council on Forest Engineering Conference: 130-142.

McIver, J.D. 1995. Deerhorn fuels reduction: economics and environmental effects. Tech. Note. BMNRI-TN-6. La Grande, OR: U.S. Department of Agriculture, Forest Service, Blue Mountains Natural Resources Institute. 6 p.

McIver, J.D. 1998. Economics and environmental effects of fuel reduction at Limber Jim. Tech. Note. BMNRI-TN-10. La Grande, OR: U.S. Department of Agriculture, Forest Service, Blue Mountains Natural Resources Institute. 12 p.

McIver, J.D.; Starr. L. 2000. Environmental effects of postfire logging: literature review and annotated bibliography. Gen. Tech. Rep. PNW-GTR-486. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 72 p.

Shindler, B. 1997. Public perspectives on prescribed fire and mechanical thinning. Tech. Note BMNRI-9. La Grande, OR: U.S. Department of Agriculture, Forest Service, Blue Mountains Natural Resources Institute. 4 p.

Starr, G.L.; Quigley, T.M. 1992. Forest Health in the Blue Mountains. Public Forums, April-June 1991. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, La Grande, OR. 84 p.

Tanaka, J.A.; Quigley, T.M.; Starr, G.L.; McIver, J. 1993. A long-term strategic plan for the Blue Mountains Natural Resources Institute. On file at: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, La Grande, OR. 16 p.

6. Field Trip Abstracts

Field trips are provided for both professionals and the public. This field trip featured visits to three ponderosa pine sites where ecosystem-based management practices had been assessed in regard to aesthetic effects, fire hazard reduction, and economic feasibility.

Sawmill Creek Research Natural Area: Management Overview

Restoration Efforts at Sawmill Creek Research Natural Area

Cathy Stewart
Fire Ecologist, Lolo National Forest

The Sawmill Creek Research Natural Area was designated in 1992 to provide an example of 5 natural bunchgrass communities, one of the best examples of rough fescue grasslands and open-canopy ponderosa pine/Douglas-fir bunchgrass habitat types in Western Montana. It slowly became infested with exotic weeds, and the continued expansion of weeds presented the biggest threats to the integrity of the native community. It was selected as a candidate for grassland restoration to recapture and maintain the natural composition and structure, improve forage in prime elk winter range habitat, and provide research opportunities. Treatments included chemical, biological, mechanical, and fire treatments.

The Sawmill Creek Research Natural Area Weed Spray Project was implemented by backpack and ATV application in 1998. Aerial spraying by helicopter was considered but dismissed due to public concerns and would have required a lengthy and expensive Environmental Impact Statement. The contractors used back pack and truck to broadcast spray 156 acres of spotted knapweed with Tordon @ 1 pint/acre and Transline @ 2/3 pint/acre, spot spray 4.2 acres of Saint Johnswort with Tordon @ 2 pints/acre, and spot spray 0.3 acres of sulfur cinquefoil with Tordon @ 1 pint/acre. The contract went for over $100 per acre, started in October, and finished in early November 1998. The contractors sprayed many more acres with ATV's than the estimated 40 acres.

Flammulated Owl Habitat

Vita Wright
Aldo Leopold Research Institute, Forest Service

Restoration efforts often focus on understanding and manipulating vegetation structure, with the assumption that restored vegetation structure will provide suitable habitat for native wildlife species. Because restoration efforts are often manipulative and irreversible, it is imperative that we understand the effects of proposed restoration efforts on the distribution and abundances of wildlife. Old-growth ponderosa pine is rarer throughout its range than it was historically. Thus, wildlife species dependent on this ecosystem may also be rarer. The Flammulated Owl, an example of a species dependent on old-growth ponderosa pine, is listed as a sensitive species by the Forest Service throughout the Rocky Mountains. Managers often consider old ponderosa pine forest stands as suitable habitat and plan restoration treatments with the intent of maintaining or creating habitat for this rare species.

The BEMRP Phase I study of Flammulated Owl habitat, which occurred on 656,317 ha of the Bitterroot and Lolo National Forests, was the first study to investigate the landscape context around occupied and unoccupied old-growth ponderosa pine stands. Results of this study suggest old ponderosa pine stands are not occupied by Flammulated Owls unless they occur within landscapes surrounded by low canopy cover ponderosa pine/Douglas-fir forest. Thus, not all old-growth ponderosa pine is currently suitable, or potential future habitat. On the local scale, restoration efforts of ponderosa pine forest within landscapes that are suitable for Flammulated Owls should maintain large trees, large snags, and variable densities of understory trees. Ponderosa pine forests probably always contained some understory tree thickets, and microhabitat studies in Colorado, Oregon, and New Mexico have documented Flammulated Owls using this understory for roosting and singing. These studies indicate nest trees may not be suitable for Flammulated Owls without the presence of some understory trees in the vicinity, presumably to provide protection from predators. Ponderosa pine restoration efforts may be most effective for Flammulated Owls and some other ponderosa pine dependent species if they occur in suitable landscapes, in addition to maintaining the necessary microhabitat components.

Restoration of Native Plant Communities Infested by Invasive Weeds—Sawmill RNA

Peter Rice
University of Montana

The Sawmill Creek was designated a Research Natural Area in 1992 to provide superior examples of fescue grassland and open canopy forest habitat types. However, a number of invasive alien plants had become established in the RNA. The noxious weeds present included small colonies of leafy spurge, dalmatian toadflax, Saint Johnswort, sulfur cinquefoil, and extensive areas of spotted knapweed. The continued expansion of these exotics threatened the integrity of native plant communities and the value of the site as elk winter range. The weed populations were mapped in 1994. An integrated weed management plan was developed as a joint effort by the Bitterroot National Forest and the University of Montana. A management research project was initiated to provide scientific documentation of weed control and grassland restoration techniques implemented at an operational scale. Herbicides, biocontrol insects, changes in access and use patterns, limited hand digging, and finally reintroduction of fire are being employed to control the weeds and revitalize native species.

Test plots sprayed with Tordon herbicide in the fall of 1996 confirmed that the native bunchgrass communities, including the native wild flowers, would respond favorably to release from competition with spotted knapweed. One hundred and sixty acres of spotted knapweed infested grasslands were broadcast sprayed by ATV, truck, and backpack sprayers in the fall of 1998. Moths (*Agopeta zoegana*) that bore out the roots of spotted knapweed were released on adjoining private land and portions of the RNA that were not suitable for ground-based herbicide applications. It is the intent that the biocontrol insects will provide long-term suppression of knapweed. Other weeds of very limited acreage were targeted for eradication or containment by chemical treatments. Now that the weeds are suppressed it is possible to reintroduce fire to the site without increasing the weed problem.

Ravalli County Weed District, adjacent private landowners, Rocky Mountain Elk Foundation, Stewart Spraying, Western Agricultural Research Center, University of Montana, Rocky Mountain Research Station, and the Bitterroot National Forest cooperated in the design and implementation of this restoration project. Experience gained on this project can serve as a model for the restoration of other high value conservation sites in western Montana that are being degraded by invasive weeds.

Larry Creek

Larry Creek: Management Perspective—Riparian Wildlife

Dave Lockman
Wildlife and Fisheries Biologist, Bitterroot National Forest

Riparian habitats are extremely important for wildlife species due to their high productivity and their structural complexity. As a result, riparian habitats support higher numbers of individual animals and greater wildlife species diversity than any other type of habitat in the western United States. This in turn increases the species diversity of the entire region since many species are found exclusively in riparian habitats.

Although riparian habitat is extremely important to many wildlife species, it is relatively rare. Riparian areas occur on only 1 percent of the entire land area in the western United States, yet 60 to 80 percent of all songbird species present in various western states breed primarily in riparian habitats. Many bird species that do not breed in riparian habitats use them during migration for refueling because of the abundance of high-energy foods such as insects and berries. Riparian habitats are absolutely critical to most of our songbird species at some point during the year. Riparian habitats are important to many other types of wildlife as well. Unfortunately, researchers estimate that 95 percent of the riparian habitats present when the western states were settled have been degraded, altered or destroyed by human activities such as dam construction and creation of reservoirs, clearing for agriculture, livestock grazing, and subdivision. Habitat changes on that scale have obviously had a negative impact on the wildlife species that use riparian habitats.

In the Bitterroot River bottom, riparian habitats have been reduced by approximately 30-40 percent since the Valley was settled, largely due to clearing for agriculture in the early years, and more recently due to construction along the river. This habitat loss has undoubtedly affected riparian-dependent wildlife species in the Bitterroot. On the Bitterroot National Forest (Bitterroot Forest), little riparian habitat has actually been lost. Instead, there has been a more subtle change—slow conversion of riparian habitats from those dominated by broad-leaved, deciduous species such as cottonwood, aspen and deciduous shrubs to those dominated by evergreen, coniferous species such as spruce and fir. The extent of this riparian conversion is unknown, but it is probably widespread and is largely a result of fire suppression. Periodic disturbance in riparian areas—typically fire or flooding—tends to favor deciduous trees and shrubs, which readily resprout, over coniferous trees, which do not. Lack of disturbance over time permits conifers to become established and grow, and they eventually overtop and shade out the sun-loving deciduous vegetation.

Josh Tewksbury from The University of Montana looked at songbird communities in a number of different riparian sites, both on private land and in the Bitterroot Forest between Hamilton and Darby. Josh found that bird species richness is highest in deciduous riparian habitats, intermediate in the upland pine-fir forest, and lowest in coniferous riparian habitats. Josh also found that 20 percent of all the bird species he detected were found only in deciduous riparian habitats (e.g., American Redstarts and Black-headed Grosbeaks), while almost all species that use coniferous riparian habitats also use the adjacent forested uplands (e.g., Golden-crowned Kinglets). Since many songbird species are unique to deciduous riparian habitats, bird species diversity declines as riparian habitats convert from cottonwood and aspen to spruce and fir. The remnants of deciduous riparian habitat on the Bitterroot Forest function as islands of diversity, which help maintain the bird species diversity of the entire area. Conversion of riparian habitat from deciduous to coniferous dominance can be detrimental to other wildlife species as well (big game forage, beavers). On the other hand, some wildlife species benefit when riparian habitats change from willow and aspen to spruce and fir (voles, marten, fisher).

As usual with wildlife habitat issues, there are trade-offs, and no one type of habitat meets the needs of all species. However, we need to recognize that riparian habitats—and especially deciduous riparian habitats—support unique wildlife communities and are thus critical to maintaining high wildlife species diversity across the landscape. We also need to recognize that deciduous riparian habitats are maintained by periodic disturbance, and that protecting them from all disturbances is a sure way to lose them and the many wildlife species that depend on them.

Deciduous Riparian Habitats: Habitats and Landscapes for Healthy Bird Communities

Joshua J. Tewksbury
Ph.D. Candidate, University of Montana

Deciduous riparian areas support more bird species than any other vegetation type in the Western United States, playing a paramount role in sustaining the diversity and abundance of birds in the West. In the forested ecosystems, deciduous riparian habitats include aspen stands, cottonwood stands, willow and alder thickets, and other deciduous shrub communities. These areas typically make up less than 1 percent of western landscape, yet they are the primary nesting areas for many birds. Over the past four years, we have observed over 105 species of birds in the deciduous habitats on the Bitterroot National Forest. We have found that the greatest diversity and density of birds are found in the largest stands with the greatest structural diversity. However, throughout the Western United States, these deciduous islands are rapidly being converted into coniferous areas, as our effective fire suppression strategies have drastically reduced the frequency of disturbance in these areas. Our research indicates that the coniferous riparian areas, which often replace the deciduous areas, support only half the diversity and density of birds as deciduous areas, and most of these birds are also found in the dryer areas. Thus, effective conservation of bird populations on the Bitterroot National Forest must include active management strategies so that deciduous habitat is not lost to conifers.

However, providing the physical habitat is only the first part of the equation—in the long run, proper management will depend on understanding the conditions that allow birds to breed successfully in these areas. By following the nesting success of over 3,000 nests of 75 different species, we have identified two distinct threats to the health of bird communities—nest predation and brood parasitism by the Brown-headed Cowbird. Brood parasites, such as the cowbird, lay their eggs in other birds' nests, leaving the other birds to raise the young. For many birds that raise the cowbird, this is very harmful because the cowbird nestling gets all of the food, and the hosts young often starve or are pushed from the nest. Both nest predation and brood parasitism have profound effects on the health of breeding bird communities, and the levels of nest predation and brood parasitism vary tremendously among different deciduous riparian patches. However, the quality of the habitat (patch size, structural complexity) does not affect predation or parasitism like it does diversity and abundance. Instead, the landscape surrounding the habitat appears to be the primary factor.

In riparian areas surrounded by coniferous forest, red squirrels are abundant, and they are common nest predators. However, in agricultural landscapes, such as many areas along the Bitterroot River itself, red squirrels are not abundant, and the primary predators are often magpies, and other birds in the Jay family. Thus, most birds sustain considerable nest losses in both agricultural and forested landscapes, but our analyses suggest that most bird species in the Bitterroot Valley still manage to reproduce to some extent when either jays or squirrels are abundant. However, the highest nest predation rates are found in the interface between forested landscapes and agricultural landscapes. In these areas, nesting birds have to contend with lots of squirrels and lots of magpies, as well as generalist predators such as raccoons and skunks. The results are that few birds escape nest predation and raise successful nests.

Cowbird parasitism, on the other hand, is strongly linked to the density of houses and farms on the landscape, and thus cowbirds are typically more abundant in agricultural landscapes. Cowbirds utilize farms and houses as feeding areas—corrals, feed lots, bird feeders, and any other predictable food source provides habitat for cowbirds. Many cowbirds travel from these locations to deciduous riparian areas because these areas have many birds that can be used as hosts. However, our research has shown that parasitism rates are primarily related to features at a local scale. The addition of one or two houses, or a single coral, within 1 km of deciduous riparian habitat appears to cause large increases in nest parasitism—often doubling the percentage of nests that are parasitized. This may cause severe declines in the breeding success of many species. However, these large changes in parasitism rates make sense in light of the fact that a single female cowbird can lay as many as 40 eggs in a season and one coral can provide feeding habitat for a large number of cowbirds. The management implications are encouraging, however. It appears that landscape change further than 1 km from an area of interest has a much weaker effect on parasitism rates. Thus, relatively small areas can act as buffers to protect these important deciduous communities.

Ecosystem management requires understanding not only the processes important within a habitat, but also the connections between habitats and landscapes. This is particularly important in the Bitterroot Valley, where the vast majority of the deciduous riparian areas exist relatively close to the interface between private and public land. To insure that we continue to have diverse bird communities in the Bitterroot Valley, it is essential that we maintain or mimic the natural disturbance deciduous forests depend on; without the habitat itself, the birds will not breed at all. Additionally, our management priorities should be in areas that are buffered from private land, where feed lots, cattle, and houses provide habitat for cowbirds and increase brood parasitism and where the nest predators of the urban landscape mix with the predators from the forest.

Riparian Forest Restoration Treatment—Larry Creek

Matt Arno
Master of Forestry Student, The University of Montana, Missoula

Current forest research has shown that fire suppression is causing many forest health problems on uplands in the Inland West. Elimination of frequent, low-intensity fires has resulted in dense thickets of conifers that have replaced the shrub and herbaceous vegetation historically present. These conifers are now experiencing stagnated growth and are susceptible to insect and disease outbreak and severe wildfires. Techniques such as improvement cutting and prescribed fire are being implemented to return to more open stands of seral species.

Many riparian areas are experiencing this same problem, but it is not being addressed, even though the consequences may be more severe than on uplands. Seral riparian ecosystems are the most highly productive wildlife habitat in the Inland West, and intense wildfires in riparian areas can produce severe erosion and water quality problems.

Concern for the effects of fire and forest practices in riparian areas has resulted in a “hands-off attitude.” This ignores the evidence that many lower elevation riparian areas experienced low-intensity fires at the rate of 2 to 5 per century prior to 1900, which maintained productive seral vegetation. However, personnel from the Intermountain Research Station (now Rocky Mountain Research Station) and the Bitterroot Ecosystem Management Research Project have recognized the role pre-settlement fire played in shaping riparian forests and the risks associated with not addressing this problem.

This project at Larry Creek is one of two designed to test “full-scale restoration” by creating a more open seral stand structure and reintroducing fire to the riparian ecosystem and an “alternative restoration” where excess trees were cut and removed from the site without the use of fire. Low impact techniques such as directional felling, hand piling, and the use of a small farm tractor with a harvesting winch on frozen, snow-covered ground were used to limit site disturbance.

These treatments were carried out in two low elevation forested riparian areas on the Lolo and Bitterroot National Forests near Missoula, Montana.

Collected data include fire history, historic stand structure, wildfire hazard rating before and after treatment, and vegetative response to the treatments.

Effects of Timber Harvesting and Burning on Aquatic Ecosystems in Larry Creek, Bitterroot National Forest, Montana

Mike Jakober
Fisheries Biologist, Stevensville Ranger District, Bitterroot National Forest

Larry Creek is a second order, Rosgen type A4 stream that contains native westslope cutthroat trout (*Oncorhynchus clarki lewisi*). Riparian timber harvest and burning have the potential to impact fish habitat through additions of sediment and nutrients and reductions in stream shade and future woody debris recruitment. Riparian timber harvest occurred adjacent to Larry Creek during winters 1995-1996 and 1996-1997. Riparian underburning occurred in September 1997. Several stream channel transects were established in Larry Creek, upstream and downstream of the harvest and burning units. These transects were measured prior to the harvest and burning treatments, and for two years after the treatments. Variables measured at each transect included channel cross-section profile, particle size distribution, water temperatures, and nutrient (N and P) levels. Monitoring of the transects failed to detect any changes in sediment, nutrients, and water temperatures resulting from the harvest and burning treatments. Fish habitat was protected by mitigation measures that included harvesting in winter over snow, placing some of the large woody debris in the stream channel, and leaving most of the overstory trees along the stream. A small reduction in stream shading has occurred in some spots, but these losses are expected to be temporary with the recovery of riparian shrubs, and have not occurred on a large enough scale to cause a detectable increase in water temperature. At present, the harvest and burning treatments do not appear to have adversely altered westslope cutthroat trout habitat in Larry Creek. However, the treatment units in this project were small, which made it difficult to detect aquatic effects. Additional research is needed before projects such as this are applied to larger areas across the forest. With larger harvest and burning units, the potential for impacting the aquatic ecosystem is likely to increase.

Lick Creek

Lick Creek: Using Ecosystem-Based Management for a Sustainable Ponderosa Pine Forest—Management Overview

Rick Floch
Acting District Ranger, Darby Ranger District, Bitterroot National Forest

Forest and rangeland ecosystems are both complex and dynamic: **complex**, in that lots of different pieces are continually interacting together, sometimes in an obvious way, like pileated woodpeckers nesting in old-growth pine snags, and sometimes in a “well, who would have thought of that!” way, like the subtle interaction between a certain type of mushroom, the candystick plant, and certain lodgepole pine stands; and **dynamic**, in that with all this interaction, things are always changing, sometimes very slowly, like a rotting log on a dry south slope, and sometimes very fast, like a wildfire.

For resource managers, the vastly complex and changing nature of publicly owned ecosystems presents a particularly unique challenge in terms of management. This challenge is well summed up in the following statements taken from the Committee of Scientists’ report, “Sustaining the People’s Lands,” when they wrote:

> For these (National Forest lands) truly to be the ‘people’s lands,’ the people must understand the land’s condition, potential, limitations, and niche in resource conservation in this country and must be willing and able to help achieve sustainability. For its part, the Forest Service can learn from the unique knowledge, advice, and values of the American people and must be willing to try new approaches, organize in new ways, experiment, learn, and adapt. To succeed, the agency must provide a supportive organizational context that encourages and accommodates this experimentation and ongoing learning.

One way of meeting this challenge is through the use of Demonstration/Research Forests—forests that have been established across the Northern Rocky Mountains and dedicated to research in the ecology and management of a wide spectrum of ecosystems. These research areas are open to visitors and offer opportunities for collaborative research and demonstration.

The Lick Creek Demonstration/Research Forest, which you will see and learn about today, was officially established in February of 1991 as a cooperative agreement between the Bitterroot National Forest and the Intermountain Research Station (now part of the Rocky Mountain Research Station) in Missoula, Montana. It emphasizes innovative methods of managing ponderosa pine dominated ecosystems for varied resource outputs.

The Lick Creek area offers a unique opportunity to propose and study different options for sustaining ponderosa pine ecosystems. Historically, the area was logged in 1906 using horses and railroads. At that time, old-growth ponderosa pine was the dominant species over much of the area, perpetuated by frequent, low-intensity wildfires. Photographs of stand conditions were taken in 1909 and approximately every decade after that date. These photos offer a unique and dramatic visual history of vegetation change over time, particularly as it has been influenced by successful fire suppression. Present day forest conditions are considerably different than historical conditions and have created significant problems in terms of unacceptable wildfire risk, particularly adjacent to private land rapidly being subdivided and developed into urban areas, insect/disease risk, and sustainability. In addition, the area has a diversity of resource values, including high recreational use, considerable elk winter range and spring calving areas, timber management opportunities to provide wood products, and interesting historical interpretation opportunities, that all add to the complexity for management of this area.

Several management scenarios for sustaining and managing ponderosa pine stands are being demonstrated at present in the Demonstration/Research forest, and considerable information pertaining to specific research questions is being accumulated over time. Field trips open to both resource managers and members of the public are held in the Forest each year. Set against the background of active research demonstrations, the Demonstration/Research Forest provides a unique opportunity (1) for the public to learn about how ecosystems function and to voice their concerns about management of these ecosystems, (2) for research scientists to plan and implement research projects relevant to today's public concerns and issues, and (3) for resource managers to also learn more about what the concerns of the public are and how to best manage ecosystems in a sustainable, responsive manner.

Effect of Prescribed Fire on Soil Nitrogen

Tom DeLuca
School of Forestry, The University of Montana, Missoula

Over the last five years we have studied the influence of prescribed fire and wild fire on soil organic matter, microbial activity and nitrogen availability in the mineral soil. Studies were initiated at Lick Creek in 1994 and were then expanded to include a number of distinct sites in western Montana. These study sites had been treated with either selection harvest, selection harvest with prescribed burning, or a no treatment control 0 to 11 years prior to initial soil analyses. Mineral soil samples were collected and analyzed for soil organic nitrogen (N), potentially mineralizable N (PMN), microbial biomass N, and inorganic N (NH_4^+, NO_3^-). Soils were also analyzed for total organic carbon (C), soluble sugars (C available to microorganisms), and microbial respiration rates. Selection harvest without prescribed burning had little or no influence on levels of plant available N or microbial activity relative to the control at all sites. Selection harvest with prescribed fire, however, significantly increased available N (NH_4^+ and NO_3^-) and soluble sugars immediately following fire. This increase was not apparent within two years following treatment. Although prescribed fire increased levels of plant available N in the mineral soil for up to one year following treatment, mineralizable N decreased to levels lower than the control for up to 11 years following treatment. Similarly, microbial activity was increased immediately following fire treatments, but was significantly lower than the control 2, 3, and 11 years following fire. In a related set of experiments, we observed a significant increase in the presence of native N fixing plants (*Lupinus* spp.) following fire. This response was most notable at the Lick Creek sites, which had been repeatedly opened by harvest prior to reintroduction of fire. The reduction in mineralizable N may enhance the ability of these N fixing plants to recolonize and ultimately supply a fresh pool of labile N that turns over more rapidly than the soil organic matter pool labile N. Further studies are being conducted in the Bitterroot to assess the effect of fire (1) on N turnover rates and plant uptake rates of N and how that may influence productivity, (2) on nitrogen:potassium (N:K) ratios and how these influence root phenolic concentrations, and (3) on the change in understory vegetation (from ericaceous shrubs to graminoids) and how this change in plant species influences soil organic matter quality as it relates to nutrient turnover.

Elk Habitat

John Ormiston
Wildlife Biologist, Bitterroot National Forest

The following is based partially on a study conducted by William F. Koncerak entitled "Determining the effects of fire restoration on elk winter range and hiding cover.

The objectives of the study were to analyze the influence of prescribed burning on forage quantity and hiding cover on elk winter range. The null hypotheses were that low- to moderate-severity fires do not affect forage quantity or hiding cover.

Changes were detected. Hiding cover was reduced for 25 to 30 years and winter range forage species increased for about 15 years post-burn. Grasses accounted for most of the forage increase; no increase in shrubs was detected.

As we implement landscape scale vegetation management and elk become more vulnerable to hunters due to reduction of hiding cover, we need to pay close attention to retaining adequate cover, or consider hunting season restrictions to assure the future of elk.

The landscape on the west side of the Bitterroot Valley contains a large percentage of hiding cover. One of the objectives of applying fire is to increase the forage resource. Koncerak found that even with low to moderate burn intensities this objective was attained.

Modeling the results of this study applied to a hypothetical 5,000 acre forested area indicated a significant increase in elk use potential until about 2,600 acres were treated. In other words, we would need to apply fire to over 50 percent of forested winter ranges to realize their potential for elk production.

Fire and Forest Succession in the Shelterwood Unit at Lick Creek

Stephen F. Arno
Rocky Mountain Research Station

Historically, the ponderosa pine forests at Lick Creek, like many throughout this region, consisted of open pine stands with several age classes, including many large trees, maintained by frequent low-intensity fires. Between 1600 and 1900, fires occurred at average intervals of about eight years in a given stand. After much of the overstory was harvested in 1906-1911, coupled with exclusion of frequent fires, dense new stands arose. In 1990 the Bitterroot National Forest invited the Intermountain Research Station (now part of the Rocky Mountain Research Station) to test techniques of partial cutting and underburning to restore open, multi-aged stands of ponderosa pine at Lick Creek.

The dense second-growth stand we will view was treated using a retention shelterwood harvest in 1992. This reduced the number of trees per acre from an average of 240 to 93, leaving the larger, more vigorous pines. Average basal area was reduced from 120 to 52 square feet per acre. Treetops were left in the woods, while the merchantable stems and their attached limbs were removed. The next spring some blocks were underburned when the duff was relatively moist, some were underburned when the duff was dry, and other blocks were left unburned. Effects of the treatments have been studied in terms of damage and growth response of overstory trees, natural regeneration, and effects on undergrowth species.

To continue this restoration process, forest managers intend to conduct additional silvicultural cutting and underburn treatments at intervals of 20 to 30 years. This should (1) allow new age classes of pine to regenerate, (2) control the stocking of both overstory and understory trees, (3) recycle fuels and nutrients, and (4) maintain undergrowth vegetation desirable for wildlife habitat.

Bitterbrush *(Purshia tridentata)* Regeneration Processes in a Ponderosa Pine Stand at the Lick Creek Study Area

Kristi D. Pflug
Master of Science Candidate, School of Forestry, The University of Montana, Missoula

Lack of natural regeneration of bitterbrush, an important browse species for elk and mule deer, is a problem throughout its range. This study sought to gain better understanding of the impacts of browsing and seed depredation and of four different forest management treatments (a control, and shelterwood cuts with no burn, a low consumption burn, or a high consumption burn) on flower and seed production and seedling recruitment. Flower production did not differ significantly among forest management treatments in 1998. Differences in flower numbers between caged and uncaged plants ($p \leq 0.001$) indicated that browsing did significantly impact flower production. Differences in number of remaining seed among caged, netted, and uncaged plants ($p < 0.050$) suggested that some reduction in seed crops might also be occurring due to seed depredation by rodents. No significant problems were found in seed viability or seedling survival on this site. The largest barrier to natural regeneration appears to be litter buildup on undisturbed sites, leading to a lack of suitable locations for rodent caching and seed germination. No seedlings were observed in undisturbed areas. Therefore, disturbance of some sort appears necessary if bitterbrush stands are desired as a future part of this landscape. Logging and/or low-intensity fires could be beneficial to the stand by providing litter removal for seedling recruitment while still retaining a number of mature bitterbrush.

Silviculture at Lick Creek

Carl Fiedler
School of Forestry, University of Montana

Existing condition (prior to treatment in 1992)

- Fire Hazard — Vertical continuity of fuels; Understory densification of both Douglas-fir and ponderosa pine
- Old growth — Scattered mortality from western pine beetle; Questionable recruitment of old growth in future
- Regeneration — Species composition, conditions skewed toward Douglas-fir; Slow juvenile growth of ponderosa pine seedlings/saplings

Target conditions

- Moderately open (50 to 90 ft^2/ac), large-tree dominated, and primarily ponderosa pine composition (≥90 percent)

Treatment objectives

- Break up vertical continuity of fuels
- Improve vigor and sustain existing old growth
- Create conditions to develop/recruit future old growth
- Reduce stand density to promote regeneration of ponderosa pine
- Reduce proportional composition of Douglas-fir to <10 percent
- Reduce ground fuels and logging slash, kill advance Douglas-fir regeneration

Treatments

- Cut/burn — Modified individual tree selection cutting to reserve density of 50 ft^2/ac, intermediate intensity broadcast burn in spring
- Cut/no burn — Modified individual tree selection cutting to reserve density of 50 ft^2/ac, no burning
- Control — No cutting or burning

Five-year results of treatments

- Fire hazard greatly reduced, particularly risk of crown fire
- Old-growth trees stabilized, moderate increase in growth
- Growth rates greatly increased in small- and mid-sized trees
- Adequate stocking and density of ponderosa pine regeneration
- Treatments visually acceptable to forest users

Outlook

- Reduced fire hazard, increased old-growth vigor, increased growth rates in small- and mid-sized trees, and adequate regeneration of ponderosa pine are positive initial indicators of a sustainable system
- Reentry interval of 30 to 35 years
- Two possible management emphases:
  - Timber production/esthetics, with old growth component
  - Old growth

7. Poster Session Abstracts

In the Bitterroot Valley, the human community is surrounded by the natural processes and wildlands literally as well as figuratively. Agriculture, timber, recreation, and a growing urban culture shape the social context for ecosystem-based management.

Use of SIMPPLLE in the Bitterroot Ecosystem Management Research Project

Jim Chew
USDA, Forest Service, Rocky Mountain Research Station

This poster will present the various ways that output from SIMPPLLE has been used in the Bitterroot Ecosystem Management Research Project. SIMPPLLE has been used on the Stevi West Central analysis unit; an individual drainage, Sweathouse Creek, within Stevi West Central; and the geographic planning unit that encompasses Stevi West Central. SIMPPLLE output is used to help quantify the trends in vegetative conditions and disturbance process. It provides a quantification of the range of variability of conditions and processes. Probability maps of process occurrence are used to create risk maps that are input into other modeling systems to help create treatment schedules. The resulting treatment schedules are evaluated in SIMPPLLE to determine if they have the desired impact of conditions and process occurrence.

The Effects of Wildfire With and Without Previous Prescribed Burn on Nitrogen Dynamics in Forest Soils

Ursula Choromanska and Thomas H. DeLuca
School of Forestry, University of Montana, Missoula

Forest burning of variable severity has long been considered a natural element controlling nutrient availability in many forests. Heat induced chemical reactions will, to a degree, oxidize a portion of accumulated organic matter, and temporarily enhance mineralization of nitrogen (N) and nutrient release to the soil. Although it is well understood that forest fires and underburning disturbances increase short term N availability in the forest mineral soil, the dynamics of soil N transformations within a few years after the event remains unclear. A wildfire in the Bitterroot National Forest in 1996 left us with the unique opportunity to study the effects of wildfire, with and without prior biomass removal via underburning, on microbial activity and levels of available nitrogen. The objectives of this study were (1) to compare N mineralization rates and N availability in mineral soil that has either been affected by a wildfire (W1), underburned prior to a wildfire (W2), only underburned (W3), or unaltered (Control); (2) to observe changes in indices of soil organic matter quality as related to changes in soil N; and (3) to monitor seasonal changes in quality and quantity of carbon (C) and N as a function of time since the fire. Data were collected four times: immediately after wildfire (fall 1996), in the spring and fall 1997, and in the spring 1998. Ten composite subsamples of mineral soil (0-10 cm depth) were obtained from each plot and analyzed for water content, microbial respiration, potentially mineralizable nitrogen (PMN), extractable ammonia (NH_4^+) and nitrate (NO_3^-), soluble carbohydrates (measured as anthrone reactive carbon), biomass N, and total C and N. Additionally, in the spring of 1997 ionic resin capsules were buried in plots for two months and analyzed for resin extractable N. Consistent with existing literature, our initial results confirm increased levels of inorganic N, soluble sugars and PMN concentrations, and enhanced microbial activity was detected as increased biomass N and CO_2 evolution immediately post-fire. Subsequent spring and fall sampling in the following year showed significant reduction in concentration of all measured indices in fire affected plots, possibly due to volatilization, leaching and plant uptake. Two years after fire, soil from burned plots, especially wildfire affected ones, had elevated concentrations of NH_4^+ and NO_3^- when compared to control; however, PMN, biomass N, and soluble sugars concentrations significantly decreased. Post-fire microbial recovery depends on the amount of available substrate, which, in turn, is a function of fire severity and time since disturbance.

Wondrous Place, Special Places

Nan Christianson
Stevensville Ranger District, Bitterroot National Forest

Cynthia Manning
USDA Forest Service, Northern Region

In summarizing their research on use of technology in public involvement, Wayne Freimund and Katie Guthrie comment, "The public must...articulate the values they hold for an area that are not described in a scientific study or technical model." This poster invites the public to describe some of those values. A map of the Bitterroot National Forest will be on display. Participants will be provided with ways to record the meaning of particular locations and Bitterroot wildlands, in general, to them. Participants' responses regarding specific locations will be keyed to the map or attached to a poster entitled, "Somewhere in the Bitterroot wildlands is a place where..." If the writer's thoughts apply to the whole Valley, or Bitterroot wildlands in general, they will be included on a poster entitled, "Bitterroot wildlands are special places because..." The display will be used at other meetings and locations as the Forest staff continues to seek information on people's "sense of place" regarding the Bitterroot National Forest. In the future, the map will be shared with Forest staff as an introduction to the rich meanings that the Forest has for those who use it and those who live in the Valley.

Influence of Selection Harvest and Underburning on Soil Nitrogen Dynamics in Ponderosa Pine Stands

Thomas H. DeLuca and Kristin L. Zouhar
School of Forestry, University of Montana

One hundred years of timber harvest and fire suppression have resulted in the conversion of once open stands of ponderosa pine forests to dense forests dominated by shade tolerant Douglas-fir. Selection harvest and harvest with underburning have been identified as possible tools to restore ponderosa pine stands to their historic ecological function. Case studies were performed at three separate sites in Western Montana to assess the influence of selection harvest and underburning on soil N dynamics in ponderosa pine stands. These sites had been treated with either selection harvest, selection harvest with prescribed underburning, or a no treatment control 1, 2, or 11 years prior to initial soil analyses. Replicate soil samples were collected over at least two growing seasons at each site and analyzed for changes in labile and stable soil organic matter, microbial activity, and available N. Selection harvest without underburning had little or no influence on levels of available N relative to the control at all three sites. Selection harvest with underburning, however, significantly increased extractable NH_4^+, NO_3^- (inorganic N) and soluble sugars immediately following treatment at the Lubrecht site. Such differences were not observed two years following treatment at the Lick Creek site or 11 years following treatment at the E/L site. Levels of soluble sugars were significantly lower than the control two years after underburning at the Lick Creek site. Potentially mineralizable N was significantly increased immediately following underburning at the Lubrecht site, but decreased to levels lower than the control one year following treatment. Levels of PMN were also found to be less than the control at the Lick Creek and E/L sites two and 11 years after treatment. Similarly, microbial biomass was increased by underburning immediately following treatment at Lubrecht, but was significantly lower than the control 2, 3, and 11 years following underburning at the Lick Creek and E/L sites. Although underburning increased levels of available N in the mineral soil for up to one year following treatment, it appears that such management may create a deficit in labile N, 2 to 11 years following treatment. Losses of labile N are a natural occurrence associated with fire; therefore, natural ecological function may be dependent upon a smaller pool of labile N. The absence of fire may result in artificially high levels of labile N that may enhance the occurrence of disease, increase the presence of exotic plant species, and reduce the presence of native N fixing plant species.

A Conservation Easement That Perpetuates Ecosystem-Based Management on a Montana Ranch

Carl Fiedler
School of Forestry, University of Montana

Stephen F. Arno
USDA, Forest Service, Rocky Mountain Research Station

Concepts of ecosystem-based management (EM) are being accepted and applied by increasing numbers of non-industrial private forest landowners in Montana and other states. One significant problem, however, is ensuring the EM is perpetuated when the land is passed along to future owners. Conservation easements have become popular as a means of ensuring perpetuity of working ranches, but in Montana few easements have addressed long-term maintenance of forest ecosystems. Recently, the Nature Conservancy decided to actively encourage EM under the premise that "conservation across entire landscapes—working landscapes—is the only way to protect enough habitat necessary to sustain biodiversity" (Nature Conservancy magazine, Nov.-Dec. 1998, pp. 18-24).

The Potter Ranch in the Blackfoot Valley is the first property in Montana where the Nature Conservancy has collaborated to ensure a form of ecosystem-based forest management. For many years, the 2,500 acres of forest on this ranch have been managed for social and ecological objectives: to maintain a natural setting with old growth ponderosa pine, to perpetuate a healthy forest, and to supply wood products and forage for wildlife and livestock. In 1998 the Potter family entered into a conservation easement with the Nature Conservancy and The University of Montana's Lubrecht Forest. This easement is unique in that it requires active management of forest resources on the ranch, including harvesting of timber in a sustainable, ecologically-based manner. Under the easement, the Potter family, Lubrecht Forest staff, and Nature Conservancy officials meet each fall to decide what management activities will be carried out on easement lands over the coming year.

The language of the conservation easement eloquently expresses the value of forest stewardship: "Grantors recognize that forests, and the stands and trees which comprise them, are not guaranteed to last forever, but are renewable resources and long-lived if managed properly. Because of the long time horizon of the forestry enterprise, forest landowners must truly be stewards, who 'borrow' the forest for their period of ownership, use it, enjoy it, and then pass it on in a productive condition. Grantors further recognize that good forest stewards direct the change that occurs in forests in ways that favor their health, usefulness, beauty, and ultimately, their renewability."

Videos of Prescribed Burning of the Bitterroot National Forest for Ecosystem-Based Management

Michael G. Harrington
USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana

Smoke from prescribed burns on our national forests is often seen in the distance, but an opportunity to see the actual flames is rare. This video presents examples of actual prescribed fires in three different situations. Fire is shown in a lightly harvested ponderosa pine stand where it is being used to reduce excessive fuels, to stimulate grass and shrub (wildlife forage) growth, and to recycle soil nutrients. Fire use is also demonstrated for thinning a stand and preparing the soil for natural revegetation of whitebark pine. Finally, we show ignition of a 1,200-acre area by helicopter at the edge of the wilderness to reduce fire hazard.

Comparing Historic and Modern Forests on the Bitterroot Front

Michael G. Hartwell and Stephen F. Arno
USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana

To provide baseline information to aid land managers, we conducted a detailed inventory of representative areas on the Bitterroot Front—the mountain slopes rising directly above the west side of the Bitterroot Valley—using plots placed on a systematic grid. At each plot, the current forest structure and the associated history of logging and fire were examined. At the same plots, evidence of historical forest conditions (circa 1900) and the stand's fire history was also collected. The study's analysis phase is not yet complete, but we can provide a comparison of the structure of historical and current forests.

In the lower elevations (4,500 to 5,800 feet) ponderosa pine was the dominant species in historic stands, comprising 51 percent of the basal area, versus only 26 percent today. Larch (at 25 percent) was second dominant in historic stands at both lower and middle (5,800 to 6,900 feet) elevations, but it is a relatively minor component (less than 10 percent) today. Douglas-fir has increased from 19 percent basal area in historic stands at lower elevations to 55 percent today. At the highest elevations studied (6,900 to 7,500 feet), whitebark pine declined from 39 percent in historic stands to 11 percent today, and subalpine fir increased from 13 percent historically to 32 percent today. Whereas long-lived, fire-dependent trees dominated the historic forests, today's forests are dominated by short-lived species that are growing in a denser structure more vulnerable to insect and disease epidemics and severe wildfires.

Effectiveness of Carbon-Sooted Track Plates for Detecting American Marten

Jacob S. Ivan
Department of Wildlife Biology, University of Montana

Kerry R. Foresman
Division of Biological Sciences, University of Montana

Covered, carbon-sooted track plates have recently been proposed as a means of determining presence/absence of forest carnivores in a given area. We assessed the effectiveness of covered aluminum track plates for detecting American marten in the Bitterroot Mountains of western Montana. On five 10.44-km^2-survey units in the study area, we captured and uniquely branded the toe pads of seven marten so that they could be identified by their tracks. Concurrently, we deployed track plates in each survey unit as per the US Forest Service protocol. Via telemetry data collected on six of the seven marten, we concluded that the branded individuals spent a majority of their time within the survey units and should have been detected by the tracking plates. However, we did not collect tracks from any of the toe-branded marten. Further, through modified telemetry systems, we found that two of the seven marten spent several minutes on several different days within 5 m of track plates without ever leaving their tracks. Despite not detecting branded marten known to reside on the survey units, we did collect tracks from unbranded individuals on four of the five survey units. Thus, the probability of detecting marten on a survey unit when they are actually present appears to be quite high, but the probability of detecting any given individual may be quite low.

Trends in Rural Residential Development in the Greater Yellowstone Ecosystem

Vanessa K. Johnson
Project Researcher, Sierra Club Grizzly Bear Ecosystems Project, 234 E. Mendenhall, Bozeman, MT 59715; (406) 582-0981; vkjk1@aol.com

Numerous public and private entities have expressed concern with the rate of development on private lands in the Greater Yellowstone Ecosystem (GYE). The conversion of privately owned open space to developed parcels poses numerous threats to the recovery and persistence of wildlife, as land lost to development is permanently removed as a functioning ecosystem component. The problem, as defined for this study, is more commonly referred to as *sprawl*, or low-density development occurring beyond the edges of centralized service areas. The primary goal of this project was to assess trends in rural residential development in the 22 counties and 3 states comprising the GYE, using both development indicators (primarily permits and logs to drill water wells and install septic systems) and available state and county development trend data. Four significant trends emerged. First, the pace of development in the 1990s in the GYE is occurring at unprecedented levels, notably in the counties of Gallatin, Madison, and Park, Montana; Bonneville, Fremont, and Teton, Idaho; and Sublette and Teton, Wyoming. Second, in Montana, trends indicate that the majority of new development is occurring in rural county areas, not in or near municipal areas. Third, a significant amount of "open space" has already been subdivided and approved for development. Fourth, development appears to be concentrating in areas of critical wildlife habitat, notably riparian corridors. The conversion of privately owned open space to developed parcels is of particular concern with regards to the long-term survival of the grizzly bear—listed as threatened under the federal Endangered Species Act in 1975. Growing numbers of people moving into bear habitat, and more bears roaming outside of protected areas, increase the likelihood of human-grizzly conflicts, and human-caused grizzly mortality. Research by Merrill and others (1998)[1] suggests that the combination of highly productive habitat, high levels of human activity, and nearness to otherwise suitable habitat makes conflict more likely. This speaks for the need for a better understanding of the patterns of human habitation in the Greater Yellowstone Ecosystem, and, more broadly, understanding the conditions associated with human-grizzly bear conflicts—which, more often than not, end in the death of the bear.

Physiological Risk Assessment of Forest Ecosystem Sustainability in the Inland Northwest

Ronni Korol
Rocky Mountain Research Station, Missoula, Montana

Interest in carbon uptake and storage, water quality and yield, and nutrient cycling within forested ecosystems is increasing. Emphasis is on maintaining sustainable forests and healthy watersheds. Recent evaluations suggest that forest integrity (ability of forests to function) and resilience (ability of forests to adapt to change) in the inland northwest may be declining. Understanding baseline levels of forest processes (carbon, water and nutrient cycles) and functioning is necessary to quantify forest integrity and resilience, and to develop physiologically based risk assessments of forested ecosystems.

We are proposing a new, long-term research project that emphasizes newly developed metabolic (e.g., growth and maintenance), physiologic (e.g., photosynthesis and carbon balance), microbiological (e.g., decomposition and nutrient balance), and biogeoclimatic (e.g., transpiration and water balance) indicators of forest resilience and integrity as well as traditional descriptors. The research will introduce a unique method of combining physiological process measurements at the leaf-to-tree scale with the stand-to-ecosystem scale of eddy covariance techniques. Measurement of carbon and water flux across all scales (leaf-forest-ecosystem) will provide the most robust and accurate assessment of forest resilience and integrity currently available. Knowledge generated from this project will supply sufficient understanding for development of new physiological relationships, validation of existing relationships, and their application across a range of forested conditions. Additionally, the development of easily quantifiable, portable, and sensitive indicators of forest resilience and integrity will facilitate comparison of sites across ecosystems, space, and time. These indicators, working in harmony with eco-physiological simulation models, can diagnose and assess aspects of forest resilience and integrity that support forest sustainability. These include diagnosing changes of water quality and yield changes of carbon sequestration and storage, as well as predicting effects of natural and anthropogenic changes in forest resilience and integrity.

There will be three types of study plots. First, an ***intensive*** tower site will support long-term measurements to assess forest processes at various scales. Second, smaller ***extensive*** study sites will be located in the same ecotypes as the tower site, but will include different stand structures, conditions, successional stages and moisture regimes. Data from the extensive sites will be used, in combination with simulation models, to extrapolate from the relationships found on the paired-tower site. Third, some ***extensive sites*** will become ***validation sites*** through installation of portable eddy-covariance-flux-systems to test the simulated landscape level physiological parameters. This experimental design will enable us to discriminate among ecosystems that may need additional intensive paired towers and those which are adequately represented by the initial tower pair.

To summarize, we wish to predict effects of natural or managed disturbance on forest resource sustainability, such as carbon uptake and sequestration, and water quality and yield. Forest managers can use the indicators, developed as a result of this research, as a tool in restoring ecosystem function, or ameliorating adverse forest impacts that have resulted from past management actions (e.g., fire exclusion and/or accidents like the introduction of white pine blister rust). Alternatively, mangers can foresee and forestall potential new adverse impacts that might happen in the future. Additionally, having the long-term infrastructure established will be valuable in linking this research to other research efforts and providing relatively quick answers to new short-term research needs. Finally, the results of the research can be used as an aid in the evaluation of periodic, point data, such as that obtained from ecosystem inventory plots or forest health plots.

Evaluating Wilderness Fire Risks and Benefits at the Landscape Scale

Peter Landres
Aldo Leopold Institute

Carol Miller and Paul Alaback
University of Montana, Missoula

The consequences of fire exclusion pose severe challenges for managers, especially in wildland-urban interface zones, such as along the Bitterroot Front. Fire managers seek to reduce fuels and risks in this zone, while striving to return the natural role of fire to wildland ecosystems. Unfortunately, managers lack the information and methods to adequately incorporate fuels management and fire programs into landscape planning activities and to objectively evaluate the risks and benefits of their decisions. A GIS-based model is currently being developed to help managers identify where and when fire is likely to threaten life and property, as well as where fire may result in the greatest benefits. The model estimates fire risk and benefit as functions of three variables, all of which may vary across landscapes: (1) probability of fire occurrence, (2) fire severity, and (3) the values ascribed to an area. The model will assist managers with go/no-go decisions in wilderness. Furthermore, it will allow managers to assess the impact of alternative management strategies on fire risk and benefit across a landscape. Output from a preliminary version of the model is presented to demonstrate the utility of the modeling.

Cooperative Forest Ecosystem Research: Bridging the Gap Through Information Exchange

Elizabeth A. Littlefield
Information Specialist, Cooperative Forest Ecosystem Research (CFER), 3200 SW Jefferson Way, Corvallis, OR 97331; littlefb@ccmail.orst.edu; (541) 737-6593

Traditionally, information exchange is an afterthought in most scientific research. After energy and funds are expended on years of data collection and analysis, little is left over for communicating results. Institutional and financial roadblocks exist, and scientists are generally not required or rewarded to convey information about their results, except in the form of a formal, peer-reviewed journal article. Consequently, an information bottleneck can occur when current research information is not reaching outside audiences in a timely manner.

With the advent of ecosystem management, and the interagency cooperation inherent in it, communication and information exchange have become powerful and necessary players in the scientific arena. It has become apparent that communication no longer means only “public relations” or “technology transfer.” Instead of having specific products that are developed after-the-fact, research programs and agencies are beginning to fund information exchange programs that work in conjunction with research projects. In this way, research projects are followed from start to finish, with information being expressed at many points along the way. Also, when opportunities arise for information exchange, there are mechanisms in place to capitalize on them.

One such information exchange program exists within The Cooperative Forest Ecosystem Research (CFER) program, which was established to facilitate management of forest ecosystems in western Oregon. Program cooperators include the USGS Forest and Ecosystem Science Center (FRESC), the Bureau of Land Management (BLM), the Oregon Department of Forestry (ODF), and the Oregon State University College of Agricultural Sciences and College of Forestry. The primary goals of CFER are to conduct team-oriented, integrated research to provide forest managers with new information to evaluate current and proposed strategies and practices associated with management of forest ecosystems, and to facilitate development of sustainable forest practices. Integral to the CFER mission is working closely with resource managers, researchers, and decision makers to develop and convey information needed to successfully implement ecosystem-based management.

The goals of the CFER information exchange program include (1) identifying and prioritizing research topics by assessing needs of managers and researchers, and those of other program cooperators; (2) facilitating continued two-way communication between managers and researchers; (3) developing appropriate mechanisms to convey information; and (4) ensuring effective and timely transfer of research information to the scientific and management community. In addition to continued assessment of information needs and meetings with CFER contacts within cooperating agencies, some projects slated for development in 1999 include a CFER Web site and newsletter, a speaker series based on the Northwest Forest Plan, sponsorship of a forest fragmentation conference, field tours describing research results from CFER projects, an interpretive trail through a density-management site, and a video package geared toward land managers.

The CFER information exchange program will continue to create multiple communication pathways that will allow transfer of information needs from land managers to researchers, as well as the transfer of pertinent research results to the scientific community, BLM and ODF management, and other federal, state, and private land owners and managers. In addition, user-friendly means of accessing information will allow additional audiences to benefit from the store of information complied, and will ultimately contribute to better-informed natural resource decisions.

FireWorks Educational Trunk

Nancy McMurray and Jane Kapler Smith
Rocky Mountain Research Station, Fire Sciences Laboratory

Sustaining fire-dependent forests in the northern Rocky Mountains requires understanding of fire behavior and fire ecology—not only by scientists, but also by the public. Key to this understanding is the concept that fire plays a different role in different forest communities, which are interconnected across the landscape. *FireWorks* is an educational trunk for students in grades K-10. It contains materials and structured curricula that provide interactive, hands-on activities for studying fire behavior, fire ecology, and people's influences on wildland fire. Students learn about fire history, characteristics that enable plant and animal populations to survive fire, and succession in three kinds of Rocky Mountain forests: ponderosa pine/Douglas-fir, which occurs on dry sites at low elevations; lodgepole pine/subalpine fir, which occurs at middle and high elevations; and whitebark/subalpine fir, a high elevation forest type.

In the past year, more than 60 teachers have learned how to teach *FireWorks*, and more than 800 students in grades K-10 have used the trunk. Research with 7th grade students by University of Montana psychologists shows that (1) *FireWorks* increases student understanding of wildland fire, (2) students can transfer knowledge from the classroom to a field setting, and (3) students studying *FireWorks* perceived their classrooms and teachers in a more positive light than students in comparison classrooms.

Occurrence and Abundance of Native Nitrogen Fixing Plants in Fire Exposed Ponderosa Pine/Douglas-fir Forests in Western Montana

Jennifer Newland and Thomas H. DeLuca
University of Montana, School of Forestry

Nitrogen (N) is commonly a limiting nutrient in forests of the Inland Northwest. Past studies in this region and other parts of the world suggest that N fixing plants play an important role in replacing the N lost from the soil in fire dominated systems. Exclusion of fire from ponderosa pine (*Pinus ponderosa*)/Douglas-fir (*Pseudotsuga menziesii*) forests of western Montana has led to widespread changes in forest structure, composition, and function. It is possible that these changes in ecosystem function have also lead to decreased abundance and occurrence of native N fixing plants. We investigated the number of N fixing species, their cover and frequency of occurrence, and soil N availability at 11 paired sites in western Montana. Two types of sites were sampled: sites that had been undisturbed since historic logging in the late 1800's and early 1900's and sites where the second growth forests had been repeatedly opened by logging and/or fire over the last 80 to 100 years. In the undisturbed sites, a control treatment was sampled along with a similar, nearby area that had been affected by wildfire in the last 3 to 10 years. Areas that had been commercially thinned or selection harvested and underburned in the last 3 to 10 years were sampled in repeatedly opened sites, along with a control that had not been affected by the most recent management activities. The frequency of N fixing plants was generally low at all sites. However, cover and frequency of N fixing plants were significantly greater in burned stands than in controls and also significantly higher in repeatedly opened sites than in undisturbed sites. Potentially mineralizable N (PMN), nitrate, and ratio of PMN to total soil N were all significantly lower in the same areas where N fixing plant cover and frequency were greater, i.e., burned stands and repeatedly opened sites. Increased density of N fixing plants in repeatedly opened sites indicated that N fixing plants may been more widespread in pre-settlement forests and that regular disturbance may be required to maintain their presence. Nitrogen fixing plants likely played an important role in maintaining long-term productivity in frequently burned ponderosa pine/Douglas-fir forests.

The Effect of Streamside Development on the Distribution and Productivity of American Dippers (*Cinclus mexicanus*) in Western Montana

Sophie A. H. Osborn
University of Montana, Missoula

Human development is playing an increasingly important role in determining the distribution and success of organisms. The American Dipper (*Cinclus mexicanus*), an aquatic songbird that is completely restricted to clean, fast-flowing streams, is a habitat specialist that may be particularly vulnerable to anthropogenic modifications to its habitat. During 1996 and 1997, I examined the effect of streamside development on the distribution and productivity of dippers in the Bitterroot Valley of western Montana. I surveyed 23 creeks, located and monitored 49 nests, and conducted extensive habitat analyses of dipper territories and non-use areas. Average dipper densities were 0.33 ± 0.12 pairs/km of stream during the breeding season. Although dipper territories were more likely to occur in less developed portions of streams, dippers did not appear to avoid developed areas, as long as the development did not affect the integrity of the streams themselves. I found no dippers in areas that had been damaged by heavy grazing. Where dippers were present, there was no significant difference between the numbers of young fledged in developed vs. undeveloped territories ($P = 0.264$). Water depth in dipper territories was significantly greater at the end of the breeding season than in non-use areas ($P = 0.001$). Whether this was a function of the types of areas that dippers were selecting for breeding or the result of dippers avoiding areas that were later dewatered for irrigation is not known. The presence of bridges, which provide nest sites for dippers, has enabled dippers to colonize the lower reaches of creeks, where natural nest sites (primarily cliffs and large boulders) are scarce. These areas may be more subject to disturbance, flooding, and predation. However, I found no significant difference between the numbers of young fledged from bridge vs. natural nest sites ($P = 0.463$). In fact, bridges, which usually occurred at lower elevations, allowed dippers to breed earlier and, in some cases, to double brood. Streamside development that does not negatively affect stream quality therefore does not seem to be detrimental to dippers and, because of bridges, may, in certain instances, actually benefit dipper populations.

An Ecosystem Diversity Framework for Understanding Landscapes

Robert D. Pfister and Michael D. Sweet
School of Forestry, University of Montana

The pattern observed from a landscape perspective is predominantly composed of topography and different “patches” of vegetation. The patches are a reflection of different physical environments and a variety of natural and man-caused vegetation disturbances. Understanding the relationships among all the patches can be aided greatly by using a classification of “patch types.”

A wide variety of vegetation classification systems have been used with considerable variation from place to place and from organization to organization. To accumulate and transfer knowledge with a classification system, standardization is desirable, if not essential. Collaborative development and demonstration of a prototype standard classification protocol is the first step in encouraging a solid foundation for communication.

The Stevensville West-Central planning unit was selected to demonstrate the application of this concept. Each of the vegetation classification variables can be used independently or in various combinations for unique ecological and management interpretations. Habitat types provide the taxonomic lower-level foundation for groupings at two levels of generalization. Standard Cover (Dominance) Types provide the most general level of stratification for vegetation composition. They are subdivided hierarchically to link to the most detailed level of forest inventory data as needed. Stand Structure types are derived from three variables: (1) size, (2) density (cover), and (3) amount of vertical layering (single-story to multi-story). Although these classification variables have been widely used, the protocols for integrating them represent a new and relatively unique formalization as a foundation for summarizing and transferring knowledge from place to place through a formal classification system.

Aquatic Biodiversity: Stoneflies (Plecoptera) in Bitterroot Streams

Andrew L. Sheldon
Division of Biological Sciences, University of Montana, Missoula, MT 59812

Mountain streams support a rich fauna of aquatic insects important in community function and of potential value as indicators of environmental change. From 1995-98 I collected adults and nymphs of stoneflies in five streams (Lick, Judd, Roaring Lion, Bear, and Gash creeks). The 47 species collected thus far represent ~40 percent of the stoneflies known from Montana. Richness varies from 18 species in the smallest catchment (Judd) to 37 species in the largest (Bear); Lick Creek, in the most heavily managed landscape, has 32 species. Although collecting success depends on being in the right place (stoneflies are zoned by elevation and stream size) at the right time (adults of many species are present only for a few weeks), the five streams share a common fauna with 25 species found in 4 to 5 streams and only 8 species apparently restricted to a single stream. Further collecting probably will increase this homogeneity. Two zoogeographic surprises were the collection of *Isoperla rainiera*, common at higher elevations in the Bitterroots but previously known only from Mt. Hood and Mt. Rainier in the Cascades, and *Megaleuctra kincaidi* (ID, OR, WA) in small temporary tributaries to Lick Creek.

In contrast to the similarity of species lists among streams, a genetics study of the abundant *Yoraperla brevis* (in press, Freshwater Biology), using cellulose acetate electrophoresis to identify 16 alleles at 5 variable loci, detected substantial differentiation between streams but similar gene frequencies at multiple sites within streams. Thus the rugged Bitterroot topography prevents dispersal and gene flow between catchments.

Diversity of stoneflies in these Bitterroot streams is high, reflecting (1) a high regional diversity of stoneflies, (2) the range of elevation and stream size within catchments, (3) the heterogeneity of microhabitats within stream reaches, and (4) the availability of special habitats such as springs and temporary streams. Although most species are widely distributed, genetic data imply significant isolation and independence of streams so recovery after impact may be slowed. Ongoing synthesis efforts should produce a decision tree capable of predicting the stonefly fauna at single sites and identifying stressed stream reaches.

The Whitebark Pine Story

Helen Y. Smith and Stephen F. Arno
USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana

Whitebark pine trees are the "keystone" or essential feature of an interesting ecological system involving birds, squirrels, bears, and the very character of high mountain habitats. Multi-stemmed whitebark pine trees hold the rocky soil on some of the harshest high elevation sites, beyond the elevational limits of other tree species. The whitebark pine tree relies on colorful jay-like birds, Clark's nutcrackers, to disperse its seed so it can regenerate. When the trees are bearing a cone crop the air is filled with the various calls of the nutcrackers. Clark's nutcrackers store seeds by planting them up to 14 miles from the tree, often in forest openings created by forces such as fire. They bury seeds about one inch below the surface, leaving no sign of their activity. The birds retrieve the fatty seeds for themselves and their young. These birds can remember several thousand spots where they have buried seeds, but the seeds left uneaten can germinate into seedlings.

Red squirrels, on the other hand, store entire cones in large caches, called middens, on the forest floor. The squirrels use the same areas for their caches for many years, leading to a huge pile of spongy cone debris. The squirrel middens, in turn, are important food sources for grizzly and black bears. Bears raid these middens to gorge on the seeds that help them to fatten up in preparation for their long winter hibernation. Bears also seek out the middens in the spring after they emerge from hibernation. Blue grouse rely on the dense crowns of whitebark pine trees where they roost and feed for much of the year. These trees provide an important thermal and hiding cover in an otherwise harsh environment.

Over the past few decades it has become clear that whitebark pine ecosystems atop the Bitterroot Mountains and elsewhere in the Northern Rocky Mountains are threatened. A fungus accidentally introduced from Eurasia, called white pine blister rust kills whitebark pine trees from the top down. Because of this, the first impact is loss of the cones, which are produced in the top portion of the tree. Since whitebark pine trees and the fungus did not evolve together, the trees have very low levels of natural resistance to this disease. Nevertheless, 3 to 5 percent of the trees exhibit resistance, but for resistance to spread, these trees need to regenerate. Historically, fires helped create openings in the forest where Clark's nutcrackers could plant the seeds of this shade-intolerant (sun-loving) tree species. Suppression of natural fires has reduced the number of regeneration sites and has allowed shade-tolerant trees such as subalpine fir to replace whitebark pine.

To counteract these threats to whitebark pine, land managers and scientists are experimenting with prescribed burning treatments, cutting competing trees, and propagating seed from wild whitebark pines that exhibit rust resistance.

Eighty-Eight Years of Change in a Managed Ponderosa Pine Forest

Helen Y. Smith and Stephen F. Arno
USDA Forest Service, Rocky Mountain Research Station

Carl E. Fiedler
School of Forestry, The University of Montana

This publication gives an overview of structural and other ecological changes associated with forest management and fire suppression since the early 1900's in a ponderosa pine forest, the most widespread forest type in the Western United States. Three sources of information are presented: (1) changes seen in a series of repeat photographs taken between 1909 and 1997 at 13 camera points, (2) knowledge from 19 authors who have investigated effects of recent ecosystem-based management treatments, and (3) the integration of findings of forest changes related to earlier treatments and to succession. The contributing authors discuss effects of historical silviculture and recent ecosystem-based management treatments, including an evaluation of various burning prescriptions in terms of tree response, undergrowth, soils, wildlife habitat, and esthetics and public acceptance.

Putting Human Dimensions Research to Work

Jane Kapler Smith
Rocky Mountain Research Station, Fire Sciences Laboratory

Kerry McMenus and Cynthia Manning
USDA Forest Service, Northern Region

Communications, collaboration, and social science research have all played a role in the Bitterroot Ecosystem Management Research Project (BEMRP). Newsletters have gone to more than 2,000 partners each year. The public has joined managers and researchers for 1 to 4 field trips every summer. Annual workshops have brought partners together to share and discuss their findings. BEMRP partners participated in collaborative planning for a zone in the Stevensville District of the Bitterroot National Forest. Research has addressed alternative ways to collaborate in planning, the nature of success in collaboration, and the effectiveness of collaborations and communications programs. Here are some key findings:

1. There is no substitute for genuine long-term relationships among stakeholders.
2. Complexity is a better model for the real world than stereotypical expectations.
3. Goals for collaborative efforts should be modest and achievable.
4. Collaborative processes and mutual learning can change participants' perceptions about ecosystems and also about the participants and the learning environment.
5. Consensus is not always an appropriate goal for collaborative processes.
6. All participants should understand constraints on a planning process; clarity about this issue is essential.
7. An essential role of the public in collaboration is to articulate values not necessarily connected to science.

The Influence of Fire and Logging on Small Mammal Communities in Adjacent Undisturbed Sites

David R. Spildie and Peter B. Landres
Aldo Leopold Wilderness Research Institute, 790 E. Beckwith Ave., Missoula, Montana 59807; Phone: 406-542-4195; FAX: 406-542-4196; email: dspildie/ rmrs_missoula@fs.fed.us

This project investigated two related and complementary questions: (1) Do timber harvesting and fire disturbances influence the species composition and population densities of small mammal communities on adjacent but undisturbed sites? (2) What are the effects of timber harvesting and fire disturbances on species composition and population densities of small mammal communities?

This study was conducted at the headwaters of Smith Creek, which drains into Sweathouse Creek, one of the drainages from the Selway-Bitterroot Wilderness to the Bitterroot Valley. Four study sites were established: Cut, an area that was clear-cut as part of a silvicultural project in 1968; Burn, an area that burned in 1988; Adjacent, an area of intact forest between and adjacent to both Cut and Burn sites; and Wilderness, as areas of intact forest within the Selway-Bitterroot Wilderness. Our intention was that the Wilderness site could be used as a "standard of reference" for the Adjacent site, the Adjacent site could be examined to look for effects of adjacent clear-cutting and burn effects, and that the Cut and Burn sites could be compared for differential effects of these two types of disturbances, one anthropogenic, the other natural.

Trapping was conducted during the months of June, July, August, and September of 1994. A total of 3,840 trap nights yielded 489 individual small mammals of 7 species: 6 species were caught in the Adjacent site, 4 species in the Cut site, 3 species in the Burn, and 2 in the Wilderness. Only the red-tailed chipmunk (*Tamias ruficaudus*) occurred in all sites, while the red-backed vole (*Clethrionomys gapperi*) occurred in both Adjacent and Wilderness sites, and the deer mouse (*Peromyscus maniculatus*) occurred in both Cut and Burn sites.

Morisita's Index of Similarity was used to compare species composition among sites. This analysis showed strong similarity between Cut and Burn sites, while there was much lower similarity among all other site comparisons. There were sufficient captures to permit reliable population estimates for *Clethrionomys gapperi*, *Peromyscus maniculatus*, and *Tamias ruficaudus*.

It appears that there were no, or at most minimal, effects of either type of Cut or Burn disturbance on the undisturbed Adjacent forest. The following support this conclusion:

1. Different species composition between the Adjacent and disturbed sites. Although the Adjacent site was surrounded by both Cut and Burn sites, the species that occurred in these disturbed sites did not occur in the Adjacent site, with the exception of the wide-ranging chipmunk. One species, deer mice, did occur in all three sites, lending marginal support to the idea that Cut and Burn sites were affecting species composition of the Adjacent site. However, there were only 2 deer mice caught only once in the Adjacent site.
2. Similar population densities between the Adjacent and disturbed sites. In terms of population density, only the chipmunk can be compared across Cut, Burn, and Adjacent sites, and its densities appear comparable across all 3 sites.

It also appears that there were only slight, or marginal, differences between the Cut and Burn types of disturbances on the small mammal communities. The following support this conclusion:

1. Similar species composition on both sides. The only difference between these sites was the occurrence of a single individual Columbian ground squirrel (*Spermophilus columbianus*) on the Cut site.
2. Similar community composition on both sites. Morisita's index, which takes into account species composition and number of individuals of each species, was very high (0.855) when comparing these sites.

In contrast to this conclusion, there are large differences in the number of montane voles (*Microtus montanus*) and deer mice caught between the Cut and Burn sites. Higher numbers of deer mice in the Burn site might be related to a great density of grass there, but this is only speculation. There were too few montane voles caught to compute reliable density estimates, so it seems inappropriate to speculate on whether there were nonrandom differences between these sites or not for this species.

MAGIS: A Decision Support System for Management of Forested Landscapes

Janet Sullivan and Kurt Krueger
School of Forestry, The University of Montana

Steve Slack
USDA Forest Service, Rocky Mountain Research Station

MAGIS is a modeling system for scheduling management treatments spatially and temporally by integrating ecological and social information at the landscape level. MAGIS can be used to optimize competing management objectives, develop alternatives, and compare costs and benefits of these alternatives. MAGIS can be integrated into the planning process as Forest Service Interdisciplinary teams develop a planning project on an area. The team identifies a number of objectives for the project area, often by consulting with local landowners, scientists and other members of the community. These objectives may include reduction of wildfire risk, improvement of forest health and species diversity, commodity production, preservation of existing old-growth stands, maintenance or improvement of wildlife habitat, road closures, improvement of recreational opportunities, and protection of visual quality. Proposed treatments to accomplish these objectives may include stand improvement cuts, regeneration cuts, ecosystem burns, campground improvements, road mitigation, and road closures. Data are entered into MAGIS for the calculation of output amounts and costs having to do with natural resources and their relationships to road networks. The economic and ecological effects of conducting or not conducting selected resource projects can then be modeled by MAGIS, thus creating quantifiable options for decision makers to consider. Treatment units and road links are assigned treatment options. MAGIS calculates the projected outputs (timber yield, wildlife habitat, sediment, runoff), costs, revenues, and effects on stand condition of proposed treatments. Proposed treatments developed by the ID team can be entered in MAGIS, which (in simulation mode) calculates the results of the schedule of treatments. More powerfully, MAGIS can be used to develop new alternatives by selecting an objective for optimization; this objective may be constrained by any combination of other objectives, including the lower and upper limits set by Forest Plan standards and guidelines. Through an iterative process a plan may be developed that meets all of the combined objectives for the project. Color-coded maps displaying the solution treatment schedule (and road construction) can be displayed in MAGIS. MAGIS solutions can also be exported to ArcView (or other GIS viewers) to display and analyze solutions in detail and by time period; desirable aspects to display might include outputs by treatment unit, revenues, network issues, costs, and stand conditions.

Mid- to Late-Holocene Vegetation Changes in the Great Basin Ecosystem Management Project Area

Robin J. Tausch, Cheryl L. Nowak, and Jeanne C. Chambers
USDA Forest Service, Rocky Mountain Research Station, Reno, Nevada 89512

The Central Nevada Ecosystem Management Project on Maintaining and Restoring Riparian Ecosystems has included a detailed investigation of past vegetation changes. These studies are based on examinations of plant macrofossils from woodrat middens samples at several locations in the project area. Over the last half of the Holocene (from 5,000 years BP to the present) cycles of environmental variation have driven major changes in the vegetation and geomorphology of watersheds in this region. While some of these changes were relatively gradual, others were precipitous, resulting in threshold changes in plant community composition and geomorphic processes. Cycles of wet and dry periods, along with possible shifts in the seasonality of precipitation, are evident. Associated vegetation responses include changes in total taxa diversity, in the relative abundance of herbaceous and woody species, and in the relative abundance of more mesic and more arid adapted species. These past changes have had major influences on the dynamics of the distribution and composition of modern communities.

A Risk-Based Comparison of Potential Fuel Treatment Tradeoff Models

D.R. Weise, R. Kimberlin, M. Arbaugh, J. Chew, G. Jones, J. Merzenich, J. vanWagtendonk, and M. Wiitala

This poster will present an overview of a study just initiated as part of the 1998 Joint Fire Sciences Program. The study will compare three models that simulate vegetation changes at landscape scales in seven vegetation types in the United States, including the Bitterroot National Forest. Tentatively, the Fire Emissions Tradeoff Model (FETM), Vegetation Disturbance Dynamics Tool, and the Simulating Patterns and Processes at Landscape Scales/Multi-resource Analysis and Geographic Information System models will be parameterized and used to simulate the effects of various fuel treatments on vegetation distribution and smoke emissions over a 100+ year time period. Additional models such as SafeForests or the Fire Effects Extension of the Forest Vegetation Simulator can potentially be added to the comparison. The ability of the models to predict current day conditions based on historical conditions will be tested using data from Yosemite National Park this year. Model outputs will be compared and contrasted in six other fuel types—chaparral, sagebrush/pinyon-juniper, northern and southern Rocky Mountain forest types, longleaf pine, and jack pine. Sensitivity analyses to identify critical model components will be performed. Simulation techniques will be used to quantify model uncertainties.

RMRS
ROCKY MOUNTAIN RESEARCH STATION

The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals.

Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

Research Locations

Flagstaff, Arizona
Fort Collins, Colorado*
Boise, Idaho
Moscow, Idaho
Bozeman, Montana
Missoula, Montana
Lincoln, Nebraska
Reno, Nevada
Albuquerque, New Mexico
Rapid City, South Dakota
Logan, Utah
Ogden, Utah
Provo, Utah
Laramie, Wyoming

*Station Headquarters, Natural Resources Research Center,
2150 Centre Avenue, Building A, Fort Collins, CO 80526