Idaho Forest, Wildlife and Range Policy Analysis Group

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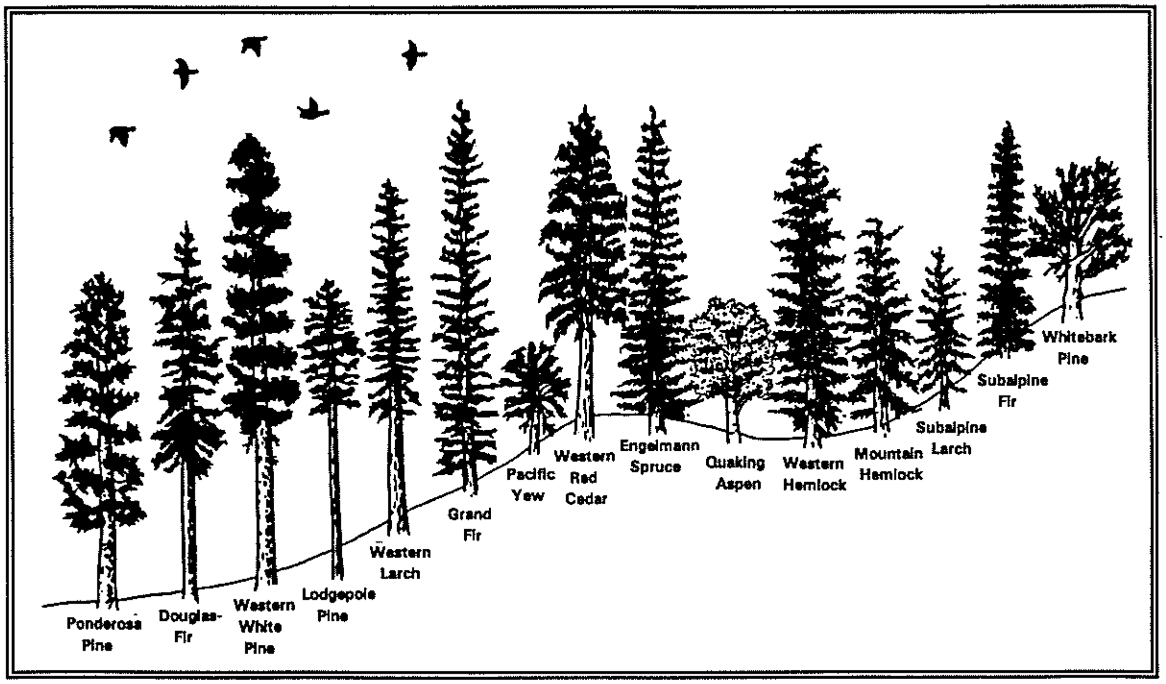
Forest Health Conditions in Idaho

by

Jay O'Laughlin, James G. MacCracken, David L. Adams
Stephen C. Bunting, Keith A. Blatner, and Charles E. Keegan, III



Idaho Forest, Wildlife and Range Policy Analysis Group
Jay O'Laughlin, Director

Idaho Forest, Wildlife and Range Experiment Station
John C. Hendee, Director

University of Idaho

- The Idaho Forest, Wildlife and Range Policy Analysis Group was established by the Idaho Legislature in 1989 to provide objective analysis of the impacts of natural resource proposals (see Idaho Code § 38-714).
- The Policy Analysis Group is administered through the University of Idaho's College of Forestry, Wildlife and Range Sciences, John C. Hendee, Dean.

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Idaho Dept. of Fish and Game
Boise, Idaho

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Boise, Idaho

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Idaho Travel Council
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Idaho Dept. of Lands
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Lewiston, Idaho

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Boise, Idaho

Jack Lavin, Coordinator
Idaho Recreation Initiative
Boise, Idaho

Bruce Bowler, Attorney
Environmental interests
Boise, Idaho

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Bureau of Land Management

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— Cover art provided by the University of Idaho Society of American Foresters —

Forest Health Conditions in Idaho

by

Jay O'Laughlin,[1]
James G. MacCracken,[2]
David L. Adams,[3]
Stephen C. Bunting,[4]
Keith A. Blatner,[5] and
Charles E. Keegan, III[6]

---

[1] Dr. O'Laughlin is Director, Idaho Forest, Wildlife and Range Policy Analysis Group, University of Idaho, Moscow; a member of the Society of American Foresters; and teaches natural resource policy.

[2] Dr. MacCracken is Research Scientist, Idaho Forest, Wildlife and Range Policy Analysis Group, University of Idaho, Moscow; and a member of The Wildlife Society, the Ecological Society of America, the Society for Range Management, and the Northwest Scientific Association.

[3] Dr. Adams is Professor, Department of Forest Resources, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow; a member of the Society of American Foresters; and teaches silviculture and forest protection.

[4] Dr. Bunting is Professor, Department of Range Resources, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow; a member of the Ecological Society of America and the Society for Range Management; and teaches fire and landscape ecology.

[5] Dr. Blatner is Associate Professor, Department of Natural Resource Sciences, Washington State University, Pullman; a member of the Society of American Foresters and the Forest Products Society; and teaches forest finance, harvest scheduling, and natural resource planning.

[6] Mr. Keegan is Director of Forest Industry Research and Associate Professor, Bureau of Business and Economic Research, University of Montana, Missoula; and a member of the Forest Products Society.

A land ethic, then, reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land. Health is the capacity of the land for self-renewal. Conservation is our effort to understand and preserve this capacity.

Aldo Leopold (1949)
"The Land Ethic"
A Sand County Almanac

... a consensus exists that western resources generally ought to be developed but that development ought to be balanced and prudent, with precautions taken to ensure sustainability, to protect health, to recognize environmental values, to fulfill community values, and to provide a fair return to the public.

Charles F. Wilkinson (1992)
Crossing the Next Meridian:
Land, Water, and the Future of the West

Regardless of what we are doing, our efforts [to resolve the "logjam" or gridlock in the forests of the Pacific Northwest] must be guided, it seems to me, by five fundamental principles. First, we must never forget the human and the economic dimensions of these problems. Where sound management policies can *preserve the <u>health of forest lands</u>*, sales should go forward. Where this requirement cannot be met, we need to do our best to offer new economic opportunities for year-round, high-wage, high-skill jobs. Second, as we craft a plan, we need to *protect the long-term <u>health of our forests</u>, our wildlife and our waterways*. They are, as the last speaker [Ted Strong, Columbia River Inter-Tribal Fisheries Commission] said, a gift from God and we hold them in trust for future generations. Third, our efforts must be, insofar as we are wise enough to know it, scientifically sound, ecologically credible and legally responsible. Fourth, the plan should produce a predictable and sustainable level of timber sales and non-timber resources that will not degrade or destroy our forest environment. And fifth, to achieve these goals, we will do our best, as I said, to make the federal government work together and work for you.

President Bill Clinton (1993)
Concluding remarks at the "Forest Conference"
April 2, 1993, Portland, Oregon
(emphasis added)

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Dr. Mark Brunson
Ecosystem management/social science
Dept. of Forest Resources
Utah State University

Dr. Richard Everett
Ecosystem management
USDA Forest Service
Wenatchee, Washington

Dr. Greg Filip
Forest pathology
Dept. of Forest Science
Oregon State University

Dr. Jo Ellen Force
Forest policy
Dept. of Forest Resources
University of Idaho

Dr. John Freemuth
Ecosystem management/politics
Dept. of Political Science
Boise State University

Dr. Marvin Henberg
Head
Dept. of Philosophy
University of Idaho

Dr. R. Ladd Livingston
Forest entomology
Idaho Dept. of Lands
Coeur d'Alene, ID

Dr. John Marshall
Tree physiology
Dept. of Forest Resources
University of Idaho

Dr. Penny Morgan
Forest ecology/fire
Dept. of Forest Resources
University of Idaho

Dr. Leon Neuenschwander
Forest ecology/fire
Associate Dean for Research
College of Forestry, Wildlife and Range Sciences
University of Idaho

Dr. Logan A. Norris
Head
Dept. of Forest Science
Oregon State University

Dr. John Ratti
Wildlife ecology
Dept. of Fish and Wildlife Resources
University of Idaho

R. Neil Sampson
Executive Vice President
American Forests
Washington, D.C.

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Barbara Bentz
Forest entomology
USDA Forest Service
Logan, Utah

Mark Brunson
Forest ecosystem management
Dept. of Forest Resources
Utah State University

Jim Byler
Forest pathology
USDA Forest Service
Missoula, Montana

Dennis Ferguson
Silviculture
USDA Forest Service
Moscow, Idaho

Steve Fletcher
Forest health management
USDA Forest Service
Baker, Oregon

Oz Garton
Wildlife ecology
Dept. of Fish and Wildlife
University of Idaho

Ken Gibson
Forest pest management
USDA Forest Service
Missoula, Montana

Sue Hagle
Forest pathology
USDA Forest Service
Missoula, Montana

John Kwader
Forest resource management
Boise Cascade Corporation
Emmett, Idaho

Ladd Livingston
Forest entomology
Idaho Department of Lands
Coeur d'Alene, Idaho

Herb Malany
Forest resource management
Boise Cascade Corporation
Emmett, Idaho

Jim Moore
Forest nutrition
Dept. of Forest Resources
University of Idaho

John Olson
Forest resource management
Potlatch Corporation
Lewiston, Idaho

Dave Van De Graaff
Forest resource management
Boise Cascade Corporation
Emmett, Idaho

Art Zack
Forest ecology
USDA Forest Service
Coeur d'Alene, Idaho

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FOREWORD

The Idaho Forest, Wildlife and Range Policy Analysis Group (PAG) was created by the Idaho legislature in 1989 to provide Idaho decision makers with timely and objective data and analyses of pertinent natural resource issues. A standing nine-member advisory committee (see inside cover) suggests issues and priorities for the PAG. Results of each analysis are reviewed by a technical advisory committee selected separately for each inquiry (see the acknowledgements on page *i*). Findings are made available in a policy analysis publication series. This is the eleventh report in the series. The other ten reports are listed in the inside cover.

Forests are important to Idaho for many reasons, and they will continue be. A prolonged drought has subjected forests throughout the Inland West to increased stress, accompanied by insect infestations and disease, creating a situation referred to by many as a forest health crisis. Some feel compelled to take action, others say there is no problem. The advisory committee suggested we undertake this project because of the large number of dead trees in Idaho forests, public controversy about what to do with the dead trees, and concerns about the effects of those actions on other components of Idaho's forest ecosystems.

Forestry research has traditionally reduced forestry problems into ever-smaller pieces. The emerging concept of forest ecosystem health and its implications for managing Idaho's forests for all the benefits Idahoans have come to expect promises to take a broader integrated approach to forestry problems.

The interdisciplinary approach of the Policy Analysis Group gives it the broad perspective needed to address how sustaining healthy forest ecosystems might proceed in Idaho. The topic is complex, and this report is necessarily lengthy. Anything less would do disservice to the emerging importance of forest health and ecosystem management.

John C. Hendee

John C. Hendee, Dean
College of Forestry, Wildlife
and Range Sciences
University of Idaho

ABSTRACT

If forest health is a statement about trees at risk of mortality from insects, diseases, and wildfire, then much of Idaho's forest land is either unhealthy or on the verge of poor health, especially in the national forests that represent two-thirds of the state's timberlands. Firs are the most prevalent trees in Idaho's forests, which were predominantly pines before European settlers arrived in Idaho. Firs are less resistant than pines to many insects and diseases as well as wildfire. Prolonged drought in southern Idaho has weakened forests, making them even more susceptible to insect epidemics and wildfires. In northern Idaho, root diseases are affecting the growth potential of mature stands. In forests throughout the state, environmental, ecological, economic, and social values are at risk. The situation can be changed by using forest management practices favoring pines instead of firs and reducing competition between trees by thinning, while protecting other forest values. Two obstacles to this course of action are public policy and public trust.

SHORT SUMMARY

Forest health is frequently discussed throughout the United States today, and is usually associated with sustainable ecosystem management. A healthy forest is more likely to be sustainable than an unhealthy one, and thus more capable of meeting the socially-determined needs and aspirations of the present without compromising the ability to meet those of the future. A healthy forest is resilient. It has the ability to respond to natural and human-caused disturbances such as fire, insects, disease, climate change, air pollution, and timber harvesting, and recover relatively quickly.

Are Idaho forests healthy? Judgments about forest health involve different perspectives and values, including political, social, scientific, and professional. Because of these different viewpoints, judgments about forest health have subjective elements. Forests throughout the state are exhibiting increased tree mortality and growth declines, conditions that some people may call unhealthy. Others suggest that this is just one more change in ecosystem dynamics.

Large areas of forest in southwestern Idaho are dying faster than they are growing. Forests in northern Idaho are among the most productive in the nation, but are losing productive potential because of root diseases. Past management practices, specifically timber harvesting and fire suppression, have created different kinds of forests than were here before European settlers arrived in the mid-1800s. Pines have been replaced by firs in dense overcrowded stands. These conditions make the forests susceptible to a variety of insects and diseases and severe wildfires, especially during drought conditions.

What can be done about Idaho's declining forest health? Because of the diverse nature of these forests, there is no single causal variable, and thus no easy fix. Intensive care can help remedy unhealthy forest stand conditions. That is, intensive forestry practices can be used to favor resistant and resilient tree species—pines and western larch. Among other things, intensive forestry practices include thinning dense stands, the use of prescribed fire, and regeneration of more resistant and resilient tree species. The alternative to intensive forestry is reduced productivity, many dead trees, and fuel conditions favorable to large and potentially destructive wildfires. Salvage logging can reduce fire hazard, and recover economic value if done expeditiously.

We know what caused current conditions in Idaho, and we know the remedy. So why don't we do it? Part of the reason is that forests are ecosystems, and we lack complete knowledge of the interactions of forestry practices with wildlife, water quality, and other forest resources. But without trees, there is no forest. There are two related reasons why intensive forestry cannot be implemented: public policy and public trust. Timberlands cover 28% of the state, and more than three-fourths of Idaho's timberlands are managed by public agencies, most of that in the national forests managed by the USDA Forest Service. Public forests, especially the national forests, are governed by policies and regulations that constrain managers from implementing intensive forestry techniques. And there may not be adequate financial resources to carry out the work necessary to change forest conditions. Public trust is intertwined with public policy. The policies implemented by national forest managers were adopted because segments of the public no longer trust the USDA Forest Service to manage the national forests in pursuit of their interests. The problem is less one of people in the agency than it is unclear and sometimes conflicting policy directives.

Idaho forests are in decline, and will continue to decline unless management action is taken. Intensively managed private forests do not exhibit similarly high levels of mortality as nearby public forests. Idaho's federal forests are at risk of insect epidemics in southern Idaho and chronic root disease problems in northern Idaho. Both situations set the stage for catastrophic wildfires that can adversely affect wildlife habitat, water quality, and public budgets for fire control to protect private property adjacent to public forests.

Catastrophic forest mortality (that is, forests dying faster than they are growing) may or may not be considered a healthy condition, depending on one's values about what forests should be used for. Most of the problem in Idaho is on the national forests, partly because most of Idaho's forests are national forests, but mostly because of the way national forests are managed. National forests comprise two-thirds of Idaho's timberlands and almost three-fourths of the timber volume. Because of that, the health and sustainability of rural communities in the vicinity of Idaho's national forests are at stake. National forests cover 40% of the state, however, 61% of Idaho's national forests are not suitable timberlands, and will likely never be subject to timber harvesting.

Forest scientists have been learning how to protect forests for decades. Forest health is an integrating concept whereby scientists from different backgrounds can work together to develop knowledge in support of management directions that will sustain ecosystems while providing for the full range of forest values society desires. Because there is no agreed upon definition of forest health, we developed one:

> ***Forest health is a condition of forest ecosystems that sustains their complexity while providing for human needs.***

Definitions, however, are not as important as the concerns they represent. Forest health is part of the bigger idea of managing forest ecosystems in a sustainable manner, which includes producing sustained yields of commodity and non-commodity values. This is a new way for resource managers and researchers to view their professional responsibilities. Resource managers and scientists are working hard to develop forest health and ecosystem management strategies, but such efforts alone will not be enough. Resource professionals must work with the public to find out what uses and conditions of the forests are socially acceptable. Only when they know what people will accept can resource managers apply research-based knowledge to sustain long-term forest health and productivity and thus provide forest ecosystems that sustain the conditions and uses that people desire.

Forest health is a useful communication device for relating forest conditions to something people understand, thus attracting their attention to management problems and inspiring them to work toward socially desired solutions. Forest health focuses attention on: [1] the <u>prevention</u> of socially undesirable forest conditions by integrating the various concerns of protecting the forest from insects, diseases, and wildfire in an ecological framework; and [2] the <u>restoration</u> of socially desired forest conditions. Forest health is important by itself and is imbedded in ecosystem management policies. Much work still needs to be done to develop and implement the ecosystem management concept, especially in the social dimension. To be successful, forest health and ecosystem management strategies need public support, and that will come only with effort.

Chapter 1. Introduction and Overview

Introduction

Forest health reflects many concerns about the sustainability of forest ecosystems. Forest health includes the ability of a forest to recover from natural and human-caused stresses or disturbances, including fire, insects, diseases, climate change, air pollution, and timber harvesting. The principal applications of the forest health concept are in integrating knowledge about forest protection, and communicating forest management concerns to the public.

This introduction explains (a) the purpose and organization of the report, (b) the somewhat controversial linkage of forest health and forest management, and (c) why basic questions about forest health are difficult to answer. Following the introduction, an overview of the entire report is provided, beginning with a discussion of the timeliness of forest health concerns in the Inland West. Because the report focuses on Idaho, a brief section describing Idaho's forest resources is provided. An explanation of how and why we developed our own definition of forest health is followed by a section on problems with measuring forest health. Then the major findings of the report are presented in a bullet list. The overview concludes with sections replying to each of the two focus questions that guided our analysis.

Purpose and organization of report. Our task, as developed by the Policy Analysis Group's Citizen Advisory Committee, was to develop replies to two focus questions: [1] Is there a forest health problem in Idaho? and [2] What can be done to either treat the forest health problems that exist, or prevent forest health problems from occurring? Because forest health is an emerging concept, replies to these questions should be considered starting points for developing a deeper understanding of the issues, rather than definitive final answers.

The report is divided into four parts, each consisting of at least two chapters. The organization and content of the chapters follows the purpose of the report. We quickly discovered that forest health has not been adequately defined or measured. Part I of this report defines forest health. Our definition (Chapter 5) was developed from ecological concepts and social concerns, including various perspectives on forest health (Chapter 2), concerns about ecosystem integrity (Chapter 3), and scientific perspectives on whether or not forest ecosystems may be considered healthy (Chapter 4).

Part II reviews the ecological and managerial factors affecting forest health, beginning with an overview of the role of drought, insects, diseases, nutrition, air pollution, animal damage, past timber management practices, and fire suppression (Chapter 6). Fire has important ecological functions in Idaho forests (Chapter 7) and excluding fire from performing these roles has management implications. One of them involves what to do with dead and dying timber to reduce the risk of catastrophic wildfire. Salvage logging controversies are examined (Chapter 8), including the economic, social, environmental, and ecological issues. The relationship between wildlife and forest health is covered (Chapter 9). The linkage between forest health and the developing concept of ecosystem management, which has healthy and sustainable forests as an associated goal, is examined (Chapter 10). The state of knowledge regarding hazards and risks associated with forest ecosystem health management is reviewed (Chapter 11). The discussion of general forest health management and policy concludes with a focus on existing and proposed forest policies that deal specifically with forest health (Chapter 12).

Based on the complex of underlying factors affecting forest health described in Part II, in Part III we review how it might be possible to measure forest ecosystem health (Chapter 13) and use available data to analyze forest conditions in Idaho (Chapter 14). In Part IV, ecological knowledge and resource management approaches to forest health are assembled in case study formats. The process of succession in ponderosa pine and western white pine forests, historically the most important forests in Idaho, is presented (Chapter 15). Forest health problems and management responses by public and private organizations in southwestern Idaho are analyzed (Chapter 16). Because forest health is an emerging concept, we conclude the report by pointing out future directions that might lead to a better understanding of forest conditions and subsequent development of effective and socially acceptable resource management strategies to promote healthy forests (Chapter 17).

Forest health and forest management. The forest health concept may be most useful as a communications device. Its primary value is to focus attention on how forest ecosystems should be managed. People can easily relate to the notion of sick or unhealthy forests. The implication is that an unhealthy condition should be avoided. Unhealthy forests will not provide a full range of goods and services or ecological values, and most people feel unhealthy conditions should be improved upon. Some people, however, dispute the idea that management can improve on nature, and believe that because they are natural processes, insects, diseases, and fires should be allowed to operate without human intervention, no matter what the consequences.

If people could come to an agreement on what a forest should or should not be used for, resource managers could design programs and implement projects to achieve those ends. These actions should avoid unhealthy conditions and promote the ability of a forest to respond to changing environmental conditions and natural or human-caused disturbances and stresses in ways consistent with management objectives.

On public lands, it is exceptionally difficult to determine what the appropriate goals or objectives for forest management ought to be, and who should determine them. Forest health is related to ecosystem management, now the guiding philosophy for most federal forest lands. On state and other public forest lands, forest health is an appropriate consideration as programs to achieve the goals and objectives for those lands are planned and implemented.

Private forest landowners also might consider whether or not their actions promote forest health. More than 70% of the nation's timberlands are privately owned, and their role in providing public benefits will continue to be an important forest policy consideration, as it has always been. The goals and objectives for the use and management of private forests are determined by private property owners.

Regardless of ownership, the health condition of a forest makes a difference to managers charged with providing the many and diverse benefits from forests that society desires. A healthy forest is resistant to the effects of low levels of disturbance. A healthy forest is also resilient, that is, it can recover from the effects of natural or human-caused disturbances more rapidly than an unhealthy forest. A healthy forest is better able to respond in an orderly way to change. Environmental conditions such as temperature or precipitation will change and so will forests. Management goals will change as people decide they want something different from the forest.

Focus questions. Two questions frame our discussions of forest health: [1] When is a forest healthy or unhealthy? [2] What can be done to make forests healthier? These questions apply to forests everywhere and are similar to those asked by the PAG's Advisory Committee in relation to Idaho's forests.

[1] When is a forest healthy?—Forest health concerns are relatively new, which greatly inhibits a simple response to this question. Recent federal laws mandate forest health monitoring (see Chapter 13). Eventually monitoring can provide objective data to help answer the "healthy" question. When that happens, scientists can develop an objective assessment framework to evaluate the data. Neither the data nor the analytical framework have yet been developed.

When describing the National Forest Health Monitoring Program, the USDA Forest Service (1992a, emphasis added) said, "Although forest condition can be specified and measured objectively, forest health carries an element of subjectivity, as it is a value judgment." However, forest health need not be a subjective value judgment. U.S. Environmental Protection Agency scientists stated that some day objective criteria might be developed to reflect important forest ecosystem characteristics and human desires. Several such criteria have been identified, but none are ready to implement (Riitters et al. 1990).

Replies to the healthy/unhealthy question are based on social as well as ecological perspectives, including perceptions of what a forest is. A forest is an ecosystem with woody vegetation as its defining characteristic. Because a forest is an ecosystem, components other than trees or groups of trees (stands) need to be assessed to make judgments about forest health. The appropriate mix of these components as measures of forest health has not been determined. Judgments as to whether or not a forest ecosystem is healthy remain subjective, even though the condition of individual components may be described objectively. Concepts such as ecosystem integrity and balance are not measurable, and therefore not useful in judging forest health.

[2] What can be done to make forests healthier?—Like the healthy/unhealthy question, this is a new concern in forestry. Replies to this question are related to what forests should be used for, and thus involve the same forest management and policy problems our society has been wrestling with for more than a century. Clawson (1975) phrased the problem well in the title of his instructive policy analysis text—*Forests for Whom and for What?*

How can forests be managed to reduce not only the effects but also the occurrence of undesirable disturbances? How should forests be managed after disturbances have killed trees? These are not new questions in forestry. Considerable management effort and research has been directed at them for more than a half-century under the general topic of forest protection. Problems associated with present forest conditions are partly a result of past protection efforts, especially wildfire suppression that has kept fire from performing its natural role, with subsequent ecological effects and management consequences. We have learned much about forest protection, but the knowledge is only now being organized and integrated in the context of forest health.

Overview

The emphasis on forest health arose in the 1980s as forests were affected by unexplained stress factors possibly linked to air pollution in the Northeast, the Appalachians, and Southern California; and as forests suffered the effects of fire, insects, and diseases accompanying prolonged drought in California and the Inland West. More emphasis is needed, because a significant increase in forest mortality (24%) was reported nationwide between 1987 and 1991, with increased mortality in all regions of the country and on all types of forest ownerships (Powell et al. 1993).

Forest health concerns in the West. Forest conditions in the Inland West have drawn national media attention in the *Wall Street Journal* (Richards 1992) and elsewhere. A little more than one year before he was named Chief of the USDA Forest Service in November 1993, Jack Ward Thomas told the *Washington Post*, "If we weren't blathering about old growth and owls, [forest conditions in the Inland West] would be the hottest story in forestry" (Gray 1992b).

Dr. John Osborn (1991)—a Spokane, Washington physician and energizing force of the Inland Empire Public Lands Council, a citizen conservation group—warned of potential catastrophe from an owl-driven shift in the Forest Service's timber program from western Oregon and Washington to the eastern portions of those states, a region often referred to as the "eastside" of the Cascade Mountains. Osborn said the eastside forests in the Blue Mountains are in a "state of biological collapse" caused by decades of chemical application, fire suppression, and logging. John Butruille—who until his recent retirement was the regional forester in charge of national forests in Oregon and Washington—agreed, and said eastside forest ecosystems are "unraveling" (Durbin 1991). However, others view these conditions as but one more step in an eternity of changes, and say these ecosystems are correcting past man-made mistakes.

These concerns in the Blue Mountains led to the formation of a multi-agency organization called the Blue Mountains Natural Resources Institute. One result is a variety of publications, some describing forest health problems (Gast et al. 1991, Quigley 1992a) and others proposing solutions (Wickman 1992, Mutch et al. 1993).

President Bill Clinton convened a one-day "Forest Conference" in Portland, Oregon on April 2, 1993, to fulfill a campaign promise. Federal forests west of the Cascade Mountains and in Northern California provide habitat for the threatened northern spotted owl, and plans for timber harvests in these forests had been suspended by judicial injunction. After listening to several dozen people address issues related to old-growth forest preservation and curtailed timber harvests, President Clinton directed his executive agencies to come up with a solution to the problem within 60 days. A task force called the Forest Ecosystem Management Assessment Team (FEMAT) was formed under the leadership of Jack Ward Thomas. Although the main focus of FEMAT was on old-growth forest ecosystems and spotted owls, some effects have spilled over to eastside forests.

Part of the FEMAT plan (USDA Forest Service 1993d) looked at conservation strategies for a diverse variety of animals inhabiting the same ecosystem as the spotted owl, including salmon. Three salmon stocks are listed as threatened or endangered and subject to the provisions of the Endangered Species Act of 1973, as is the northern spotted owl. Other salmon stocks in the region are imperiled and could be listed in the near future. The three listed salmon stocks pass through portions of westside and eastside forests as they navigate the Columbia and Snake River system on their to and from spawning grounds in Idaho. Thus Idaho forests are linked to ecosystem management concerns driven by the spotted owl.

An interagency effort called PacFish (Pacific Fisheries) was initiated more than two years before FEMAT, and focused exclusively on management guidelines for riparian and upland habitat adjacent to salmon-bearing streams throughout the Pacific Northwest, including the Columbia and Snake River system. PacFish and FEMAT salmon habitat recommendations are closely linked.

Requests by U.S. Congress members in 1993 created two parallel efforts to assess the health of eastside forest ecosystems, but neither included Idaho. The first assessment was requested by Speaker of the House Thomas Foley (D-WA) and Senator Mark Hatfield (D-OR), and resulted in the 5-volume Eastside Forest Ecosystem Health Assessment (Everett et al. 1993).

The second eastside assessment was requested by seven other members of Congress and asked scientific societies—The Wildlife Society, American Fisheries Society, and Ecological Society of America among them—to make recommendations on how eastside forest ecosystems should be managed. According to the *Journal of Forestry* (1993c), the resulting product emphasized protecting the "health and integrity" of regional biotic elements as well as the processes on which they depend. Interim findings were reported in late 1993, and included 11 recommendations. Specific prohibitions and preventative measures were recommended for conserving eastside old-growth forests and riparian areas. Two panels were recommended, one to establish long-term forest health management guidelines, another to develop a strategy for ecosystem and regional landscape restoration (*Journal of Forestry* 1993c).

Management changes in the Blue Mountains, other eastside forests, and Idaho are sure to follow in the wake of national attention focused on the situation. The Blue Mountains ecoregion includes portions of the Boise and Payette National Forests in southwestern Idaho. These Idaho forests have problems similar to those in the Blue Mountains. A forest health management strategy is being implemented in the Boise National Forest because of elevated mortality levels from insect outbreaks and severe wildfires associated with six years of drought conditions that began in 1987. During 1992 and 1993, the Boise National Forest met its annual allowable sale quantity of timber almost exclusively with dead trees.

(**Note:** ecoregion, allowable sale quantity, and many other technical terms are defined in the **Glossary.**)

Idaho forests. Idaho forests, especially those in the northern part of the state, are among the most productive timberlands in the nation (Wilson and Van Hooser 1993). These forests contain a diversity of tree species, as most of them occupy mountainous terrain. This diversity is illustrated on the cover of the report and graphically portrayed in Figure 1-1.

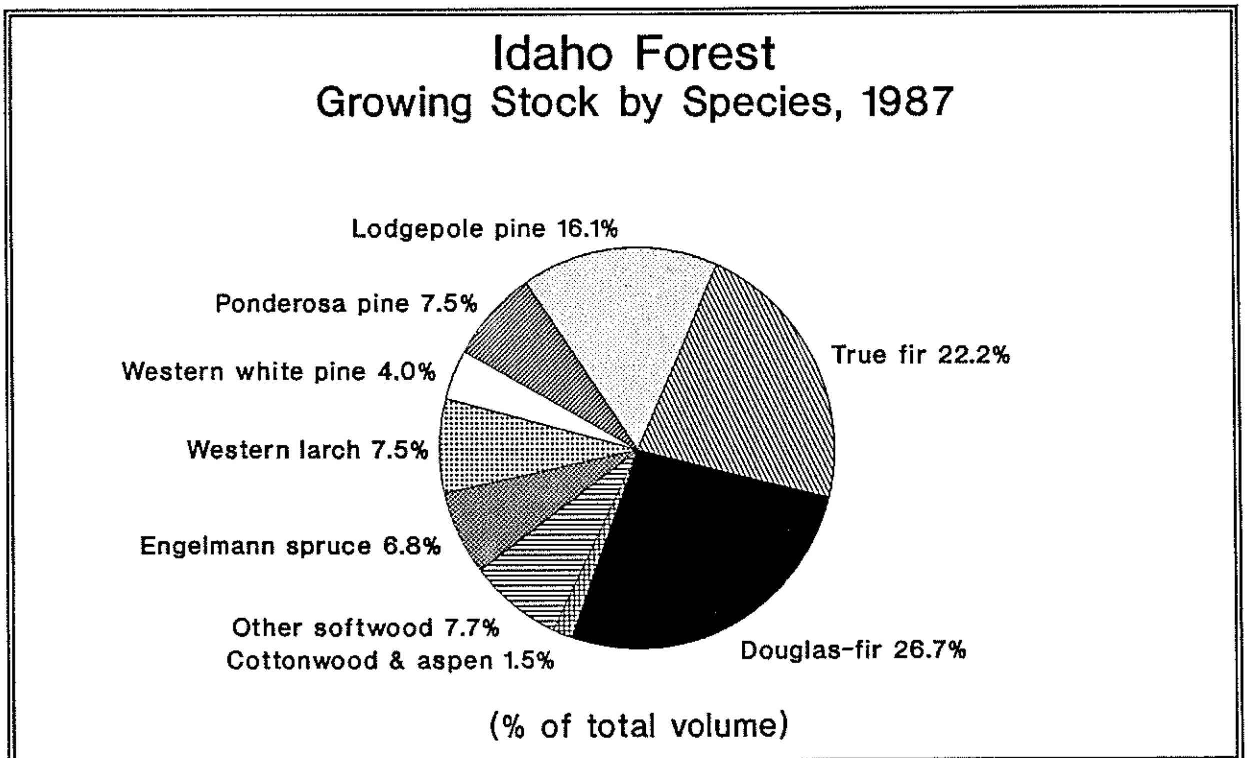


Figure 1-1. Forest growing stock volume in Idaho by species, 1987.

Source: From data in Waddell et al. (1989).

Timberlands occupy 28% of the state's land area, and are defined as forest lands that can produce 20 cubic feet of wood fiber per acre per year and have not been legally or administratively withdrawn from timber harvesting. In other words, wilderness and other reserved areas are not considered timberlands. As illustrated in Figure 1-1, Douglas-fir and true firs (primarily grand fir) now account for almost half (48.9%) of the growing stock volume on Idaho's timberlands. Three species of pine comprise slightly more than one-fourth (27.6%) of the forest volume. A variety of other softwood (or conifer) species compromise the remaining one-fourth of Idaho's forests. Hardwoods (almost all cottonwood and aspen) are only 1.5% of Idaho's forest volume (Figure 1-1).

As illustrated in Figure 1-2, the ten national forests in Idaho contain about two-thirds (67%) of the timberlands and almost three-fourths (73%) of the forest growing stock. National forest lands identified as suitable or tentatively suitable for timber production represent only 39% of the national forest land area in Idaho. The rest of the national forests are not considered suitable for timber production for physical, environmental, social, legal, or

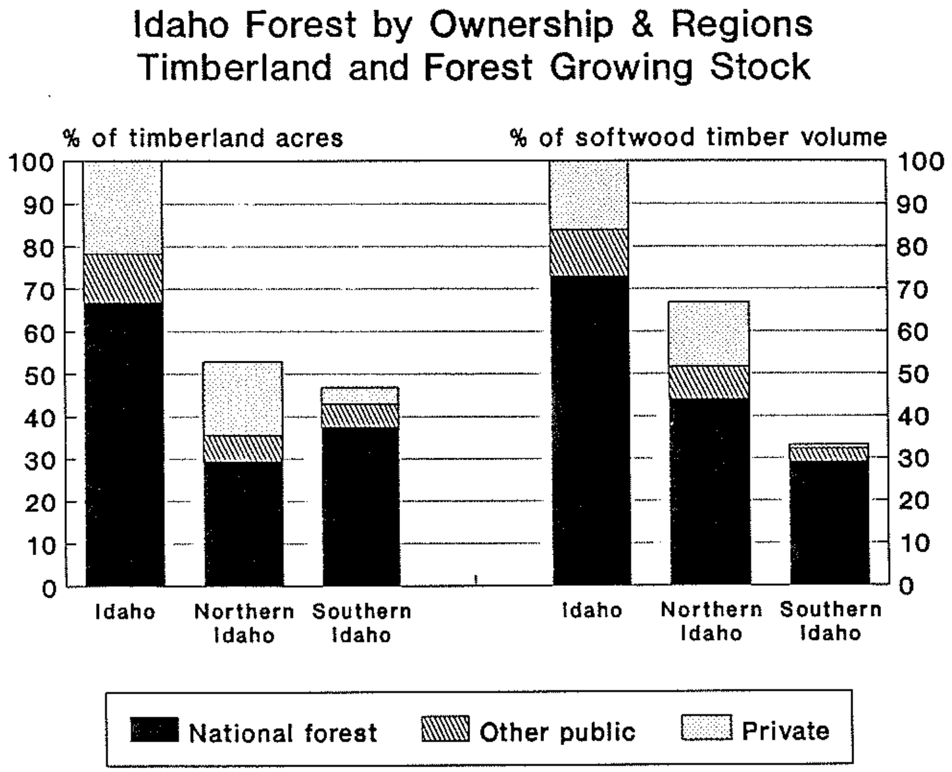


Figure 1-2. Timberland acres and forest growing stock volume in Idaho by ownership category and distribution in northern and southern Idaho.

Source: Compiled from data in Waddell et al. (1989), Waddell (1992), Wilson and Van Hooser (1993) and individual national forest land and resource management plans.

administrative reasons. In total, all national forest lands cover about 40% of Idaho. No other state comes close to having such a large percentage of its lands in national forests; Oregon ranks second with 25%.

Timberland acreage is almost evenly divided between northern (53%) and southern Idaho (47%), with the Salmon River the dividing line. Average precipitation is higher in the north, enhancing forest productivity. The distribution of forest growing stock reflects this, with two-thirds (67%) of it in northern Idaho and one-third (33%) in southern Idaho (Figure 2). The three national forests in northern Idaho and the seven in southern Idaho are administered by two different regional offices of the USDA Forest Service, the Salmon River again the dividing line.

What is forest health? Discussions of forest management policy in the western states now routinely include concerns about forest health. How can you tell if a forest is healthy or not? No widely accepted definition of forest health exists (Riitters et al. 1990). Until forest health is adequately defined and measurement standards developed, it is difficult to say if a forest is healthy or not.

As a starting point, the Random House (1971) unabridged dictionary provides four definitions of health. All but one applies to the general condition of the human body and mind. The fourth and broadest definition of health is "vigor; vitality: *economic health.*"

We synthesized a definition of forest health after reviewing what is known about the concept, and how others have described, defined, or used the terms forest health, ecosystem health, and forest ecosystem health.

Because a widely accepted definition is lacking, we developed one:

> ***Forest health is a condition of forest ecosystems that sustains their complexity while providing for human needs.***

We began the review and synthesis with various perspectives on forest health and then focused on the emerging concept of ecosystem health and how it relates to human health. The scientific merit of various terms associated with forest health were also addressed; for example, "catastrophe" has a scientific meaning, and "balance of nature" does not. "Resilience" and "sustainability" often are used with forest ecosystem health, and their meanings were examined. These concepts are difficult to measure, but convey important meanings.

Forest health judgments carry an element of subjectivity, even though the condition of various forest ecosystem components such as trees, water, or wildlife can be measured objectively. How those components can be assembled to assess forest ecosystem vigor, vitality, or health as an objective measure is a difficult and uncompleted task.

Forest health is a controversial topic, especially when salvage logging of dead and dying timber is involved. In the USDA Forest Service's (1988) first attempt at a strategic plan for forest health management, the nature and importance of socially perceived problems was addressed:

> Forest health is a complex subject with both real and perceived problems which can arouse strong emotions. Such problems justify nationwide concern. The actual problems are the product of events occurring over a long period of time. The perceived problems reflect an incomplete understanding of forest ecosystems, the biological processes operating within them, and alternative views of the purposes to be served by the forest.

Even with complete understanding of ecosystems, controversies would prevail because of the different perceptions people have about the purposes and uses of forests.

A political commentator in the nation's capital (Swisher 1992) described social problems with forest health succinctly: "'Forest health' has become a buzzword among timber state lawmakers, but the sound grates on the ears of environmentalists like a chain saw." Wickman, a USDA Forest Service entomologist, warned that forest health "is an ambiguous buzz word and as such is an over-used and misused anthropomorphic catchword" (quoted in Osborn 1992c). Despite these attempts to preempt the term, forest health discussions persist.

Our forest health definition attempts to reduce ambiguity. We found evidence that some environmentalists recognize the serious forest health problems in the Inland West, which blunts the sharp criticisms above. Although the analogy with human health is imperfect, forest health can be an effective communications tool.

When is a forest healthy? Forest health is an elusive, yet useful, concept. Forest health provides a medium for discussion of forest conditions relative to human needs and desires, and a framework for measurement of ecosystem indicators that can be used to assess general ecosystem condition or health. Although individuals may come to similar conclusions about the condition of a single ecosystem component using an objectively measured indicator, the value-based aspects of forest health make objective measurement difficult and ensure recurrent debates.

Two approaches for judging the health of a forest can be used as a starting point. The first is to focus on forest management objectives, the second is to focus on forest ecosystem function (Monnig and Byler 1992). The first approach includes the full range of forest values people feel are important. The second includes facts as to how a forest works, or how a forest ecosystem functions. This second approach can also describe what people think a forest should be, thus making the maintenance of functional ecosystems an objective of management. Two important points follow: [1] both approaches are necessary and must be linked together in any scheme for sustainable ecosystem management, and [2] both approaches involve the opinions and values of people, making social concerns obligatory considerations for forest health and sustainable ecosystem management.

Management-oriented approach.—According to the USDA Forest Service (1988, 1993c), "an unhealthy forest inhibits managers from achieving objectives; a healthy forest does not pose such obstacles." A healthy forest may not be insect-free or pathogen-free, but sufficiently free of pest damage to meet management objectives (Byler and Zimmer-Grove 1991). Furthermore, a forest can be maintained in such a condition that it will meet the objectives of future generations, which may be different from today and require maintaining various options for the future.

One challenge raised by this objective-oriented definition is that objectives must reflect limitations posed by ecosystem characteristics or properties. Another challenge is that management to achieve objectives requires a clear and explicit statement of objectives so managers know whether they are on target. Much of the forest policy debate about forest management stems from disagreement over management objectives, particularly on public forest lands. For national forests managed by the USDA Forest Service, this debate centers around the ambiguities of "multiple use" management (see Chapter 13 in Cubbage et al. 1993). For state forest lands in Idaho, debate over objectives centers around the purposes of the federal land grants to Idaho at the time of statehood (see O'Laughlin 1990).

For private lands, the management objectives debate is over the appropriate role of government in defining public benefits from private lands and the use of various tools for encouraging or discouraging actions by private landowners. Private property rights are exclusive but not absolute, as government reserves certain property rights in order to protect public values (Barlowe 1978). This is a contentious point today as forest policy discussions focus on how to sustain a wider array of values than in the past, including clean water and habitats for imperiled wildlife.

Ecosystem-oriented approach.—According to Monnig and Byler (1992), this approach means that a forest in good health is a "fully functioning" community of plants and animals and their physical environment; or as they said, "an ecosystem in balance." Some will argue that such a "balance" is too obscure, others that this "balance" can be stated as a management objective. The complex nature of ecosystems makes the specificity implied by the term "balance" elusive.

Monnig and Byler (1992) suggested that pre-European settlement conditions in the Inland West could be used as a possible reference point for assessing the health of various ecosystem components. This historic range of variability is useful in understanding how ecosystems functioned in the recent past. However, that does not necessarily recommend the historic range of variability as a management goal.

Monnig and Byler (1992) said that judgments of forest health need to include information on ecosystem function as well as management objectives. Objectives must reflect limitations posed by ecosystem properties. They said "severe" outbreaks of insects and disease are sometimes signals that forests have "crossed ecological limits." In the end, the health of forests in the future will depend on management activities that promote the "natural" structure, composition, and function of ecosystems (Monnig and Byler 1992). Mlinsek (1991) agreed: "What we need is a forest where nature's properties are safeguarded when trying to manage the forest." Those properties are ecosystem components such as soil, water, trees, and animals, and ecosystem characteristics such as resistance and resilience.

Maintaining "natural" ecosystem properties is indeed an important consideration, if society determines this to be important for particular forests. The replacement of the word "natural" with "desired" would better incorporate social concerns into forest health and ecosystem management discussions, and perhaps alleviate concerns some people express about distrust of professional authority associated with forest health and ecosystem management implementation programs.

Major Findings

The major findings contained in this report are summarized with the following points, taken from the conclusions of each chapter. They appear under subheadings identifying the four parts of the report. (References to discussions in particular chapters are included.)

Towards a definition of forest health

- Forest health is a condition of forest ecosystems that sustains their complexity while providing for human needs (Chapters 1, 5).
- Judgments about forest health involve different perspectives and values, including political, social, scientific, and professional. Because of these different viewpoints, forest health has subjective elements (Chapter 2).
- In 1992, 85% of 800 randomly sampled Idahoans who were polled considered insect infestations and disease in Idaho forests a problem (Chapter 2).
- Sustaining forest health is a principal focus of the evolving concept of ecosystem management (Chapters 2, 10).
- Forest health is concerned with a forest ecosystem, not just trees or stands of trees. But without trees, there is no forest (Chapter 3).
- Ecosystem integrity is not currently a measurable concept, and therefore not useful to make judgments about forest health (Chapter 3).
- A healthy forest is <u>resilient</u>. It has the ability to respond to natural and human-caused disturbances such as fire, insects, disease, climate change, air pollution, and timber harvesting, and recover to a socially desired state within a characteristic period of time (Chapter 4).
- Forest health is a multi-disciplinary concept, rarely mentioned in forestry literature before 1990 (Chapter 5).
- Forest health is a useful communications device for relating forest conditions to something people understand, thus attracting their attention to management problems and inspiring them toward socially desired solutions (Chapter 5).
- As is true in other health contexts, it may be easier to identify when a forest is unhealthy in one or more aspects than it is to define exactly what healthy means (Chapter 5).
- Forest health focuses attention on: [1] the <u>prevention</u> of socially undesirable forest conditions by integrating the various concerns of protecting the forest from insects, diseases, and wildfires in an ecological framework; and [2] the <u>restoration</u> of socially desired forest conditions (Chapter 5).

Management and policy considerations

- Many factors affect forest health, including natural and human-caused disturbances and variations in climate (Chapter 6).
- Trees weakened by moisture stress are more susceptible to insects and diseases as well as wildfires (Chapter 6). A 6-year drought that began in 1987 has affected Idaho forest conditions.
- The importance of the role of fire in Idaho's forests cannot be overstated. Idaho forests were formed and maintained by fire. Suppression has excluded fire from its historic role and led to changes in species composition and dense forest stands. In hindsight, fire suppression may not have been the best way to manage forests (Chapters 7, 15). However, the USDA Forest Service and other public agencies were directed to prevent and stop wildfires, and they performed this dangerous and challenging assignment very well.
- Salvage logging is useful for reducing fuel levels to protect remaining vegetation and soils from catastrophic wildfires, and recovering economic values. It does, however, need to be conducted under ecologically and socially acceptable guidelines. Some dead woody material needs to remain on site for wildlife habitat

and soil development. Salvage logging on root-diseased sites may not be appropriate unless accompanied by reforestation of species less susceptible to root disease (Chapters 8, 17).

- Wildlife are a component of forest ecosystems. The direct use of wildlife as indicators of ecosystem health is difficult because of the diversity of wildlife species, their different habitat requirements, and lack of sufficient knowledge about these requirements (Chapters 9, 13).
- Forest health stands on its own as a concept, and is a goal of ecosystem management. Norris et al. (1993) said the condition of the forest landscape is the dominant focus of ecosystem management. Forest health, being the condition of a forest ecosystem, is thus a dominant focus of ecosystem management (Chapter 10).
- Declining forest health, however measured, is a symptom of a problem. Treatment of the symptom may improve the condition of the ecosystem, but as in human health, it may not alleviate the cause of the problem (Chapters 10, 13).
- A healthy forest is <u>sustainable</u>, capable of meeting the socially-determined needs and aspirations of the present without compromising the ability to meet those of the future (Chapter 10).
- Factors that predispose forests to pest outbreaks include tree species composition poorly suited or adapted to a site, overstocking, and old age. All of these risk factors can be reduced through management activities. Unless that is done, all ecological, economic, and social values associated with forests are at higher risk than need be (Chapter 11).
- Additional research efforts focused on the development of hazard and risk rating systems would be useful to help managers determine which stands of trees need attention, and what management programs could help ensure sustainable forest ecosystems (Chapters 11, 17).
- Legislation at the national level has been introduced to address some of the forest health situations that have arisen in the Inland West. Additional funding and management flexibility to treat unhealthy conditions has been proposed (Chapter 12). Such action may be necessary on some national forests (Chapter 16).

Determining forest health conditions

- Objective indicators of forest ecosystem condition can be specified and measured, but forest health assessments contain subjective value judgments which must be clearly recognized (Chapter 13).
- Forest health can be measured, but at least three judgments need to be made: [1] selecting a representative set of indicators to measure ecosystem health—vegetation, wildlife, and watershed as a minimum; [2] developing standards for using indicator measures to assess conditions; and [3] resolving value conflicts regarding these judgments (Chapter 13).
- Forest scientists and managers, working with their customers, can identify, define, and determine ranges of desired conditions for a set of measurable characteristics in each forest ecosystem. These measurements can be useful in helping evaluate the condition of the forest at any time, in relation to conditions desired by society (Chapter 13).
- The presence of non-native vegetation and wildlife may be a key indicator of ecosystem condition (Chapter 13).
- "Forests can be considered healthy when there is an appropriate balance between growth and mortality" (Norris et al. 1993).
- Comprehensive and intensive inventories of a few indicators representing commodity and non-commodity values will improve forest health assessments, as well as forest planning and management decisions, by enabling understanding of ecosystem characteristics of stands, habitats, streams, and landscapes (Chapter 13).

- The species composition of trees in Idaho forests has changed. Ponderosa pine and western white pine were once predominant. Douglas-fir and grand fir are now the predominant species (Chapter 14).
- Wood volume in Idaho forests increased by 12% between 1952 and 1987. Annual volume growth has been twice the annual timber harvest during that period (Chapter 14).
- On the Boise and Payette National Forests in southwestern Idaho, forest stands identified as suitable for timber production were dying faster than they were growing in the late 1980s and early 1990s (Chapter 14). Neighboring private industrial forests did not experience similarly high mortality rates (Chapter 16).
- In northern Idaho, mature stands on the national forests are experiencing elevated levels of mortality from root disease. Inventories of private and other public lands do not indicate similarly elevated levels of mortality. However, the two different data sets are not directly comparable. Some attention to improved forest health inventory information seems necessary (Chapter 14).

Towards a forest health management strategy

- To promote healthy forests throughout the state, management attention should focus on two things: [1] restoration of tree species best suited to each site, in most cases ponderosa pine, western larch, and rust-resistant western white pine (Chapter 15); and [2] prevention of unhealthy conditions by maintaining stand density levels that reduce competition between trees for moisture, nutrients, or both (Chapter 16).
- Thinning to alter species composition and reduce stand density is the most important part of a forest health management strategy (Chapter 16). Root-diseased areas require different approaches (Chapters 6, 14, 15).
- Formal plans for national forests have not adequately considered the impacts of insect, disease, and wildfire outbreaks in Idaho and subsequent actions necessary to sustain forest health and long-term productivity (Chapters 16, 17).
- The forestry profession is currently undergoing substantial changes. New planning approaches and management strategies are being developed to sustain the broad range of forest ecosystem values desired by society. These changes need the support of forestry professionals and forest owners, including the public, who collectively own more than three-fourths of Idaho's forests (Chapter 17).
- Forests are in decline in Idaho, and because of the diverse nature of these forests, there is no single causal variable, and thus no easy fix. Forest health has promise as an integrating concept whereby scientists from different backgrounds can work together in support of management to sustain ecosystems while providing for the range of forest values society desires (Chapter 17).
- The forest health research agenda includes silviculture, hazard rating and risk analysis, integrated inventories, and modeling. Special attention needs to be given to wildlife as indicators of forest ecosystem health (Chapter 17).
- Forest health is related to ecosystem management. Much work still needs to be done to develop and implement ecosystem management, especially in the social dimension. In the end, only when forests are viewed from the larger landscape perspective that ecosystem management promises can multiple use be considered a feasible strategy (Chapter 17).

Are Idaho's Forests Healthy?

The suppression of wildfire has changed the composition of trees in Idaho. The shift in composition of trees in Idaho forests from pines to firs has forest health implications. Historically, the most important timber species in Idaho were ponderosa pine and western white pine. Both have declined since 1952, ponderosa pine by 40% and western white pine by 60% (see Figure 14-3). Byler et al. (1994) estimated that the extent of western white pine may now be only 10% of what it was in 1900.

The high mortality rates in Idaho's national forests are a result of this shift. Pines are able to better resistant many types of insects and diseases that affect firs. Thus pines are better adapted to many Idaho forests.

Tree growth and mortality analysis. Public concern about forest health in Idaho is greatest in southwestern Idaho. The reason for this is revealed by analyzing the growth and mortality data from forest plans for Idaho's national forests. Averaged across all ten national forests, mortality was 18.3% of gross annual growth, the measure of forest health suggested in a task force report of the Society of American Foresters on Sustaining Long-Term Forest Health and Productivity (Norris et al. 1993). Of the five national forests that have more than 2 billion cubic feet of growing stock volume, the Boise and Payette National Forests had, respectively, mortality at 31.3% and 24.9% of gross annual growth, well above the average. Of the five other national forests, the Targhee, with 1 billion cubic feet of growing stock volume, had mortality at 28.3% of gross annual growth.

The forest health situation on the Boise and Payette National Forests has worsened since the drought began in 1987, and is cause for concern, if not alarm. Our analysis, summarized in Figure 1-3, can be stated succinctly—trees in these forests are dying faster than they are growing. McGuire (1958) defined such situations as "catastrophic mortality." Most people would likely agree that such a high level of mortality is an unhealthy condition, but no standards for making that judgment have been developed. The condition of trees is an important feature of forest ecosystem health, but the complexity of ecosystems is such that soil, water, and wildlife components of forests might need to be considered.

Figure 1-3 shows that the range of variability in this measure of mortality ranged from a low of 15% to a high of almost 35% across the Inland Northwest during periods of measurement at the statewide level from 1952-1987. By overlaying this range of variability in the region with data for Idaho forests, the results in Figure 1-3 reveal that the Boise National Forest was within the regional range in 1954 and 1979, and outside it in 1987 and 1992. The Payette National Forest was at the upper limit of the range of variability in 1979, and in 1991 was well beyond it, when mortality was 1.4 times gross growth. Mortality on the Caribou and Targhee National Forests was at 25% and 28% of gross growth in the mid-1980s, respectively, and just at the upper limit of the regional range. The Nez Perce National Forest was last inventoried in 1979, and showed no evidence of a problem. Nor did the Salmon, Idaho Panhandle, and Clearwater National Forests in the mid-1980s. Inventory data for 1990 on the 3.5 million acres of forests outside national forests in northern Idaho showed mortality as 17.1% of gross annual growth, well below the upper limit of the regional range for 1987 (Figure 1-3).

Is mortality a problem in Idaho forests? From the data that are available, tree mortality fell outside the regional range on the two national forests in southwestern Idaho (Figure 1-3). Both the Boise and Payette National Forests have recently experienced levels of mortality that exceeded gross annual growth. The forests also have declining gross annual growth, which also contributes to an unfavorable relationship between growth and mortality. To the extent that tree growth and mortality data reflect forest health, it may be said that the Boise and Payette National Forests both have a forest health problem on lands suited for timber production. If more current mortality data for some other Idaho national forests were available, it might be expected to reveal symptoms of forest health problems from the drought in southern Idaho and root disease in northern Idaho.

What about the rest of Idaho? Forests cover 41% of the state; timberlands are part of that, covering 28% of the state. Analysis of forest mortality conditions on all Idaho timberlands is provided in Table 1-1 and explained in the

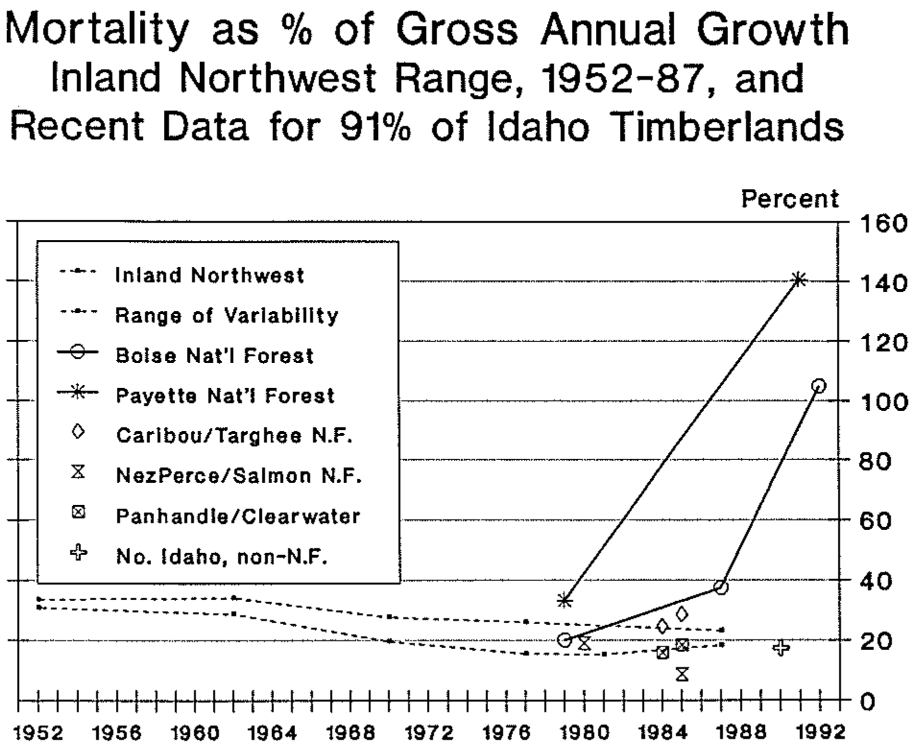


Figure 1-3. Timber mortality as a percentage of gross annual growth trends; Inland Northwest range of variability in Idaho, Montana, and the eastern portions of Oregon and Washington, 1952-1987; with most recent data representing 91% of Idaho timberlands.

Source: Adapted from USDA Forest Service (1958, 1965, 1973, 1982), Benson et al. (1987), Waddell et al. (1989), Waddell (1992), Wilson and Van Hooser (1993), and Payette National Forest and Boise National Forest inventory data and 1992 estimates furnished to the authors.

remainder of this section.

The area in southwestern Idaho represented by the Boise and Payette National Forests, and Boise Cascade Corporation lands that lie between them, are 19% of Idaho's timberlands. Boise Cascade's timberlands are not experiencing the same rate of forest mortality as the two neighboring national forests. The difference is explained by the management approaches of the organizations.

Another 28% of Idaho's forests are in the south central and southeastern portion of the state. Most of these timberlands are national forests, and inventory data for them are not current enough to compare with data from the Boise and Payette National Forests. Forest growth and mortality data from the mid-1980s indicated slightly elevated mortality/growth ratios on the Caribou and Targhee National Forests. The Bureau of Land Management has 3.8% of all Idaho timberlands, with two-thirds of them in southern Idaho. A recent inventory of BLM timberlands in southeastern Idaho revealed that 56% of the timber volume was "alive and healthy," 21% was infested with Douglas-fir bark beetle, and 23% was dead (USDI Bureau of Land Management 1992).

Most of Idaho's timberlands (53%) and forest volume (67%) are north of the Salmon River. The three national forests there represent 29% of the timberland base in the state, and 43% of the forest volume (Figure 1-2). The health of these forests is of major concern because of root disease problems (Hagle and Byler 1993). Soil and moisture conditions in northern Idaho are such that these are, as Wilson and Van Hooser (1993)

Table 1-1. Forest health conditions in Idaho.

Region and Ownership Category	**% of Idaho Total**		**Forest Condition** (expressed by forest growth and mortality)
	Timberland	**Forest Volume**	
Northern Idaho National Forests	29%	43%	No problem apparent in mid-1980s forest resource inventory data. Forest pathology surveys taken since 1985 indicate elevated levels of mortality in mature stands due to root disease and 40% reductions in productivity (S. Hagle and J. Byler, personal communication and unpublished papers).
Northern Idaho Other Public & Private Forests	24%	24%	No problem apparent in early 1990s forest resource inventory data.
Southwestern Idaho (mostly National Forests)	19%	15%	Annual mortality exceeds gross annual growth. On average, on suitable timberlands, forests are dying faster than they are growing on both the Boise and Payette National Forests. Intermingled industrial forests do not have similarly elevated mortality levels.
South Central and Southeastern Idaho (mostly National Forests)	28%	18%	The Targhee and Caribou National Forests had slightly elevated mortality/growth ratios in the mid-1980s. A recent inventory on BLM forests in southeastern Idaho showed high levels of mortality.
State of Idaho Total	100%	100%	Forests throughout southern Idaho are suffering elevated levels of mortality from forest structure problems (species composition and stand density) exacerbated by drought. National forests in northern Idaho have elevated mortality levels from root diseases that threaten long-term productivity; inventory data show other public and private forests do not have elevated mortality/growth ratios.

said, among the most productive timberlands in the nation. But past management activities—fire exclusion and timber harvesting—and the introduction of white pine blister rust have changed the composition of these forests from pines to firs, with attendant management problems. Firs are adversely affected by root diseases, a natural component of northern Idaho forests that once acted, in concert with wildfire, to limit the abundance and distribution of firs.

Recent forest inventory data is not available for other national forests comparable to that for the Boise and Payette National Forests. However, forest pathologists have been studying the root disease situation in northern Idaho since 1985, and their data reveal that mature forests throughout northern Idaho are experiencing very high mortality rates, averaging 3% to 4% in mature stands, which is well above the expected regional range of 0.5% to 0.7%. As a result, these forests have experienced 40% productivity loss (J. Byler and S. Hagle, personal communication; Byler et al. 1994). (Further discussion of the ecological reasons and an example of projected productivity decline are presented in Figure 15-2.)

Private and other public forests—that is, other than national forests—in northern Idaho represent 24% of Idaho's timberlands and forest volume. Recent inventory data for these forests do not indicate elevated levels of mortality (Wilson and Van Hooser 1993). This may be a result of different management practices on these lands than on the national forests, or different techniques for measuring mortality used by forest inventory personnel and forest pathology specialists, or both. More work is needed to ascertain the effect of root diseases on the productivity of northern Idaho forests and the effectiveness of management treatments in mitigating root disease effects.

Forest Health Management Alternatives

Prevention of unhealthy conditions and restoration of healthy conditions are called for in Idaho's federally-managed forests. The causes of current forest conditions are known. Stand structure has been altered by timber harvesting and fire suppression. Fire no longer performs its natural role of controlling species composition and stand density. Before European settlers arrived in Idaho, fires established and maintained extensive pine stands, and those stands have now largely been replaced by firs. These stands are dense, increasing competition among individual trees. When limited moisture conditions occur, as during the recent drought, weakened trees are less resistant to insects and diseases, and prompt epidemic outbreaks as well as situations favoring catastrophic wildfires.

The solutions are known. Restoration of healthy conditions and prevention of unhealthy conditions involve management actions to alter species composition and stand density. Some species of trees are better adapted to certain site conditions than are others. Changing species composition by favoring the trees best adapted to a site (that is, those most resistant to insect and disease disturbances) is an obvious solution. On many sites in Idaho, that will mean ponderosa pine, western larch, and rust-resistant western white pine instead of Douglas-fir and grand fir. Species composition is especially important on sites affected by root diseases.

Stand density control and species composition changes can be achieved by intensive management practices. Thinning the number of trees on a site to reduce competition for limited moisture or nutrients is appropriate on many sites. This involves either felling some selected trees and removing them, or restoring the role of fire through prescribed burning, or both. The risk of catastrophic wildfire can be reduced by thinning and by removing dead trees. Risk of insect and disease epidemics may be reduced in some cases by removing dead or dying trees. On sites affected by root disease, species composition changes are also called for, and in some cases may require regeneration practices.

Forest health and forest ecosystem management are part of the "sustainability" value associated with forests. Forests are defined by trees, however soil, water, wildlife, and other values need to be part of forest health management. To prevent unhealthy forests, managers will need to think in terms of curing the underlying cause rather than merely treating the symptoms of unhealthy conditions. Such management requires a long-term view of how ecosystems function across large areas of the landscape. Ecosystem dynamics mean that particular structural conditions can be perpetuated or sustained only at a very large, or landscape, scale.

The objectives for and uses of a particular forest need to be decided by people. Objectives have to be set within the physical and biological capability of the ecosystem. Achieving a healthy and sustainable forest ecosystem may become a stated objective of forest managers, but sustainable and healthy ecosystem goals will not define the uses for a particular area. Those uses need to be consistent with management objectives, and attainment of desired ecosystem conditions. The related concepts of forest health and ecosystem management will not make the job of forest managers any easier. The concepts are new and the goals are far more complex than before. Forest health and ecosystem management put management tasks in a different and broader context. These tasks will require the development and application of new ideas and tools, such as landscape-level management, and new approaches for involving people to determine forest management objectives and desired forest conditions.

Forest management strategies. At least five forest management strategies are available: intensive and extensive forestry (both are variations of the traditional forestry approach), adaptive forestry, ecosystem management, and no management. Idaho is endowed with tremendous forest wealth, and there are appropriate places for all five types of management across the different types of forest ownerships in the state. The choice is a function of the objectives of the forest landowner made within the bounds of public policies affecting forestry. The strategies differ as follows.

Intensive forestry.—This forest management strategy aims to sustain a high volume and quality of timber by applying the most appropriate management techniques and silvicultural practices. High levels of capital and labor inputs are used, with environmental concerns operating as constraints.

Extensive forestry.—This strategy involves low level applications of operating and investment costs to a forest property. However, the Idaho Forest Practices Act ensures that minimum reforestation and water quality standards are maintained.

Adaptive forestry—.This type of forest management is capable of adapting to social changes and demands on the forest; of adapting to characteristics of the ecosystems and sites where it is applied; of adapting to new scientific knowledge and techniques; and of adapting to new conditions yet to be experienced, such as global climate change, drought, fire, etc. By maintaining diverse and fully functional ecosystems, both management and the forest can adapt and respond (Adams 1992).

Ecosystem management.—This strategy is now the underlying philosophy of federal forest management. It arose from the USDA Forest Service's "New Perspectives" program in the early 1990s. A universally accepted definition has not been developed. Ecosystem management involves managing forests to provide a diversity of ecosystem types and states in a mosaic pattern across a large-scale landscape (probably at least 100,000 acres), allowing for production of commodities and other services consistent with socially-determined goals describing desired forest uses and conditions.

Ecosystem management is related to adaptive forestry described above. It offers to private and other public ownerships intermingled with federal forests whatever advantages are associated with coordinated planning. These advantages could include (a) coordinated analysis of cumulative watershed effects for compliance with the Clean Water Act of 1987, and (b) the possibility of extending consultations for endangered species incidental take permits to private forest owners and state agencies. These permits are available to federal agencies (but to no one else) through the process of interagency consultation under section 7 of the Endangered Species Act of 1973.

No management.—No timber harvesting or forestry activities are undertaken, including in some cases no wildfire control. The underlying assumption is acceptance of whatever consequences may arise from the operation of ecological processes.

If an ecosystem health problem arises, no management is akin to what philosopher Eugene Hargrove (1992) called "therapeutic nihilism"—a term used to describe the mid-19th century notion that because the cure can be worse than the disease, nature knows best. This idea is sometimes invoked in nature preservation arguments today (Hargrove 1992).

Does nature know best when it comes to managing ecosystems? Ecologist Daniel Botkin said, "When you do nothing, you'll get something you didn't expect" (Kaufmann 1993). (See discussion in Chapter 4.)

Forest health, management strategies, and ownership objectives. All forest ecosystem values, whether environmental, ecological, economic, or social, are related to the condition or health of trees. The question whether forest owners should promote healthy forest conditions—or, more pragmatically, avoid unhealthy conditions—is directly related to their management objectives. If owners decide their forests should be healthy, stands of trees can be managed to provide goods and services for human needs while avoiding unhealthy conditions. This can be done under any of the strategies described above, except the no management alternative.

Private and "other" public forests.—Industrial forests, many other private forests, and most state forest lands in Idaho are managed primarily for timber production. Unhealthy forests (however defined) are undesirable because present and future economic values are placed at risk. Intensive management practices are used routinely on private industry and state forest lands to reduce the risk of insect, disease, and wildfire losses.

Non-industrial private forest landowners are likely to follow the extensive management strategy, perhaps because they perceive forest health management costing them money. However, thinning can more than pay its own way, depending on the size of trees to be thinned.

The University of Idaho follows adaptive management strategies on the College of Forestry, Wildlife and Range Sciences Experimental Forest near the Moscow campus.

National forests.—The majority of Idaho's forests are in the National Forest System managed by the USDA Forest Service (Figure 2). Management objectives and goals for the national forests are matters of national public policy. Forest health considerations for four types of land area classifications need to be considered in the national forests: [1] designated wilderness and other areas legally or administratively reserved from timber harvest, [2] areas identified as unsuitable for timber production, [3] roadless areas identified as suitable for timber production, and [4] roaded areas identified as suitable for timber production.

[1] Wilderness areas. In designated wilderness areas, an argument can be made that nature should prevail, and insects, diseases, and wildfire allowed to operate so scientists can better understand natural processes. However, fire suppression over many decades weakens the argument that Idaho wildernesses are natural systems. Nonetheless, most patches of dead trees or burnt-over areas in wilderness will eventually support the vegetation and associated values that were once there.

A dilemma arises. Although the appearance of wilderness is not particularly relevant when viewed from a scientific perspective, scenic values of wilderness are also recognized in the Wilderness Act of 1964, and research supports the proposition that people don't like the looks of dead trees. Trail maintenance is performed to protect wilderness resource values, and in some cases maintenance of forest health may be appropriate for protecting the full range of wilderness values.

Another dilemma is that sometimes natural forces can overwhelm human efforts to control them, and wildfire, insects, and diseases can spread from wilderness to adjacent lands. Although intensive forestry practices may be antithetical to the wilderness concept, there is a provision in the Wilderness Act (section 4 (d)(1)) that allows "such measures as may be necessary in the control of fire, insects, and diseases, subject to such conditions as the Secretary deems desirable." The economic and social costs associated with large and intensive wildfires are widely recognized as undesirable, and argue against the no management alternative, even in wilderness areas.

[2] Areas "unsuited" for timber production. In national forest areas not suitable for timber production, other resource values—watershed, wildlife, forage, recreation, and aesthetics—argue against allowing wildfire, insects, and diseases to run their course. Indeed, many of these areas are unsuitable for timber production because watershed protection and wildlife habitat values were recognized as greater than timber production values. Together with wilderness areas, these "unsuited" lands represent 61% of all national forest lands in Idaho (Table 1-2). These lands will likely never be scheduled for timber production.

There are dilemmas, however. Healthy watersheds (however defined) will benefit from healthy forested riparian buffer strips. Some forest management practices may be necessary to protect buffer strips, particularly those designed to reduce fire hazards that can affect watershed health. Wildlife habitat may also be enhanced by certain forest management practices.

[3] Roadless areas "suited" for timber production. Unroaded areas in the national forests identified as suitable for timber production spark much of the controversy regarding forest health. There are 9.4 million acres of national forest roadless lands in Idaho, and some wilderness advocates would like to see the majority of these lands added to the National Wilderness Preservation System (see MacCracken et al. 1993). Forestry practices undertaken for any reason in roadless areas, including forest health, are therefore likely to be challenged.

Because 2.1 million acres of roadless areas have been identified in forest plans as suitable for timber production (LeVere et al. 1991, Table 1-2), it can be argued that these forests should be maintained in healthy and productive conditions, meaning timber values on these lands should be protected. These areas represent 10% of all national forest lands in Idaho and 14% of all Idaho timberlands (Table 1-2). Roadless areas were identified by interdisciplinary teams as suitable for timber production and considered as such in public participation activities during the planning process.

We do not propose to settle the contentious arguments regarding Idaho's roadless areas, but suggest that some forestry practices may be appropriate in high risk areas. For example, a prescribed burning program to promote forest health could be implemented without jeopardizing wilderness suitability.

[4] Roaded areas "suited" for timber production. National forest roaded areas identified in forest plans as suitable for timber production cover 5.9 million acres, or 29% of the national forests in Idaho and 41% of Idaho timberlands (Table 1-2). Healthy and productive forests are appropriate goals for these lands. When these forests are unhealthy (however that is measured) some creative management policy solutions may be needed to overcome the inflexibility of forest plans that did not provide for such contingencies. The appropriate course of action on these lands involves intensive forest management practices including thinning, prescribed burning, and regeneration of species best suited to the site.

Controversies regarding forest health have arisen because it is possible in some cases to exclude sales of dead timber from environmental analysis and administrative appeals, thus drawing angry responses from environmentalists. Too often, discussions of forest health have been reduced to arguments about salvage logging.

What about salvage logging?—Dead trees provide benefits affecting many forest values. Too many dead trees can threaten the very same values. Standing dead trees provide homes for woodpeckers and other forest denizens. When they fall, dead trees build soil and in some locations provide instream habitats. Dead trees, however, create the potential for catastrophic wildfires, which can negatively influence wildlife, watersheds, and scenery as well as vegetation. When done with sensitivity to social, environmental, and ecological concerns, a case can be made for

Table 1-2. Possible forest health management strategies on national forest land area classifications.

National Forest Land Classification	National Forest Lands		National Forest Timberland as % of Idaho Total	Forest Health Management Strategy
	Acres	% of Total		
Wilderness, designated Wilderness, recommended	4,037,270 1,292,006	20.0% 6.4%	0% (a) (b)	Control wildfire, and possibly insects and diseases, to prevent spread to adjacent lands and protect the full range of wilderness values—recreational, scenic, scientific, educational, conservation, and historical use.
Unsuitable for timber production	6,941,043	34.3%	12% (c)	Control wildfire, and possibly insects and diseases, to prevent spread to adjacent lands. Forestry practices are inappropriate for enhancing timber production, but may be appropriate for protecting and enhancing wildlife, watershed, and scenic values.
Roadless: suitable for timber production	2,066,500	10.2%	14%	Control wildfire, and possibly insects and diseases, to prevent spread to adjacent lands. Prescribed burning (and possibly salvage logging and thinning by helicopter) may be appropriate to promote forest health and other values placed at risk by unhealthy forest conditions, without jeopardizing wilderness suitability.
Roaded: suitable for timber production	5,886,943	29.1%	41%	Control wildfire, and possibly insects and diseases, to prevent spread to adjacent lands. Forest health can be restored, and unhealthy conditions prevented, by using intensive forestry practices. These include thinning, prescribed burning, fertilization, and regeneration of resistant and resilient species—especially genetically improved varieties. Intensive forestry is preferable to extensive forestry for promoting healthy forests in many situations. If healthy and sustainable forest ecosystems are a desired goal, intensive practices can be compatible with ecosystem management, especially with an adaptive management strategy.
All national forest lands	20,223,762	100%	67%	Keeping forest lands in healthy condition is an appropriate strategy to sustain forest ecosystems.

(a) 3,051,000 acres of forest land that meet the physical definition of timberland have been legally or administratively reserved and are no longer subject to timber harvesting or considered as timberlands.

(b) Acreage and percentage undetermined, but included in "unsuitable for timber production" percentage.

(c) 1,751,557 acres of "unsuitable" and "recommended wilderness" lands are classified as timberlands.

salvage logging based solely on the ecological argument of fuel management to protect resource values. This argument also has an economic dimension, because preventative treatment to reduce fuels can reduce subsequent costs of wildfire control. The recovered economic value of salvaged timber is a side benefit, but should not be overlooked. In Idaho, dead timber salvaged from national forests has been considered to be part of the allowable cut. Although it has become a focal point in forest health debates, salvage logging is only one part of a forest health management strategy.

The real issue is how to sustain a socially-determined array of forest ecosystem values. That is the rationale for keeping Idaho's forests healthy—especially the national forests that belong to every citizen of Idaho and the nation.

PART I. TOWARDS A DEFINITION OF FOREST HEALTH

Chapter 2. Perspectives on Forest Health

Forest health concerns are a new feature in both forest ecology and forest management policy discussions. The focus on forest health today stems primarily from the USDA Forest Service (1988, 1993) strategic plan for protecting the health of the nation's forests.

Values and facts both influence how natural resources are managed in the best interests of society. Values and opinions held by different individuals and groups dominate public discussions. The discovery of facts regarding natural resource management stems from the scientific process. Values and opinions often muddle public understanding of the facts. We will try to sort out these two different perspectives throughout this report in order to provide a factual basis for discussion of forest health conditions. We encourage others to do the same by recognizing that there is a subjective element in judgments about health. It may be valid for someone to argue that a somewhat "unhealthy" forest is "good," because people with dissimilar values may interpret the same facts differently.

It is important to develop the concept of forest health so people can appreciate that the condition of forest ecosystems sometimes can be improved upon by management prescriptions and preventative actions, much as human health can sometimes be improved by medical prescriptions and preventative care.

Political Perspectives

Forest health has become part of the forest policy dialogue at the national level. At the conclusion of the historic Forest Conference in Portland, Oregon, held on April 2, 1993, President Bill Clinton said, "... as we craft a [forest management] plan, we need to protect the long-term health of our forests, our wildlife and our waterways."

The U.S. Congress has passed laws that authorize programs for monitoring forest health (see Chapter 13). Congressman Larry LaRocco (D-ID) and Senator Bob Packwood (R-OR) introduced forest health bills in 1993.

These words and actions by the nation's chief executive and legislature recognize that maintaining forests in a healthy condition is nationally important. However, the term "forest health" has not been given meaning in any measurable sense, so various segments of society have reacted differently to the concept.

Social Perspectives

The social dimensions of forestry are closely related to the objectives owners have for their forests, and by public opinion. Because substantial areas of forest in the western U.S. are publicly owned, government as a forest owner plays a prominent role in public forest policy. In addition governments at all levels make the rules that private forest owners must abide by. Government is presumed to act in response to public opinion. Public opinion on forest health is mixed.

At public forums on forest health in the Blue Mountains, people from local and regional communities indicated they wanted ecosystems restored, catastrophic fires prevented, insect and disease damage reduced, economic stability increased, and flows of forest products continued. People who participated agreed ecosystem management was an appropriate approach, and felt special attention should be given to maintaining biodiversity, including sensitive species, fisheries, big game, and fragile habitats, especially riparian and old-growth forests. People suggested that managers should mimic natural processes and reintroduce fire, and use historical landscapes and unmanaged sites as points of reference (Everett et al. 1993).

Environmental groups don't think forest health is necessarily an appropriate way to frame these concerns. For example, Francis Hunt, lobbyist with the National Wildlife Federation, described forest health "as nothing more than a thinly veiled attempt by industry to increase the timber cut and weaken environmental laws" (Swisher 1992). Aplet (1992), an ecologist with The Wilderness

Society in Washington, D.C., referred to the Blue Mountains when he asked, "Is there really a forest health crisis?" His reply: "The forest health crisis may not be as bad as it is described to be." The reply was based on three observations: [1] the data documenting the extent of the crisis are difficult to interpret, [2] there is evidence the situation is natural and non-threatening, and [3] there is evidence the reported mortality is actually beneficial. Aplet (1992) concluded by saying, "The cure [salvage logging] may be worse than the disease." The salvage logging issue is analyzed in Chapter 8.

Whether evidence of dead or defoliated trees on 53% of the forest lands in the Blue Mountains national forests (Gast et al. 1991) represents a crisis or not is a value judgment. As Aplet (1992) said, the data are difficult to interpret. Some environmental groups believe there is a problem. Osborn (1992a) wrote, "Forest ecosystems of the Northwest are sick, and some are in critical condition." He proposed salvage logging guidelines and wanted fire used to restore the health of some of these forests (Osborn 1992b, 1992c).

Professor Bob Lee (1991), resource sociologist at the University of Washington, takes both ecologists and economists to task for sometimes ignoring the needs of real people in forest management debates:

> Concerned citizens, especially in a democracy, will not accept resource management decisions that disrupt their way of life, including their livelihood, recreation pursuits, and sense of community. This social scientific fact is often overlooked by proponents for preserving biological legacies, just as it was overlooked by proponents for maximizing the economic value of forests. Biological legacies cannot be maintained unless social and cultural legacies are also maintained.

The reverse is equally true. Biological legacies sustain aspects of society and culture. These concerns relate directly to forest health issues.

Philosophers are among those who have addressed the need to incorporate the aspirations of people into ecosystem health concerns. Their main point is that social and ecological needs must be considered together. Norton (1992) stated that policies should be designed to allow human cultures to thrive without changing the life support functions, diversity, and complexity of ecological systems. Social needs must be tempered, and the intuitive idea of a "healthy" system is one that is valuable beyond benefits expressed as consumptive preferences. Human activities must be constrained so as not to destroy the health and integrity of self-organizing ecological systems that provide the environmental context for economic and other human activities (Haskell et al. 1992, Norton 1992).

Public opinion research. In 1992, the Idaho legislature created the Idaho Forest Products Commission and, as Director Betty Munis (1992) said, gave it a mission "to provide programs that result in an informed public that understands and supports balanced, responsible management of Idaho's economically vital public and private forests." One of the first actions of the commission was to sponsor a public opinion survey. In September 1992, 801 Idaho residents were interviewed by an independent polling firm on a variety of forestry issues. Three questions dealt with "forest health" issues, and revealed public support for management attention to dead and dying trees. The questions and responses, as summarized by Dan Jones and Associates (1992) were worded exactly as follows:

Q: *Do you think that insect infestations and disease in Idaho forests is a serious problem, a small problem, or not at all a problem?*

A: The vast majority of residents (85%) consider insect infestations and disease in Idaho forests a problem, most of which feel it is a serious problem. In fact, only 5% of respondents say insect infestations and disease in the forests is not at all a problem.

Q: *From what you know or have heard, are insect infestations and disease in Idaho forests increasing the danger of large forest fires?*

A: Three in five interviewees (60%) say the presence of disease and insect infestations in the forests increases the danger of large forest fires, while one in five disagree. The remaining respondents are not sure whether infestations or disease increases the risk of forest fires.

Q: *Now I'd like your opinion on the salvaging of burned, dead or dying timber. Do you feel the forest industry should be allowed to immediately salvage this timber on federal forests other than wilderness or other special set-aside lands?*

A: Idahoans express wide agreement (84%) that the forest industry **should** be allowed to salvage burned, dead, or dying timber from federal forests not designated as wilderness or on other special set-aside lands. In fact, only 6% of respondents feel such timber should **not** be salvaged by the forest industry.

Public opinion elsewhere supports maintenance of healthy forests. In Colorado, where mountain pine beetles have caused extensive damage, survey research by Walsh et al. (1990) revealed that the general public is willing to pay for the protection of forest quality to maintain trees greater than 6 inches in diameter. Total annual willingness to pay averaged $47 per household. One-fourth of this value was to protect recreation use benefits, the remainder was for preservation values that included having access to forests in the future, knowledge of their existence, and as a bequest to future generations. The estimation of public benefits in this Colorado study did not include timber values, so it is not directly applicable to Idaho. The point is that people place a value on having forests, and are willing to pay to have managers protect forests from insects and other agents that affect forest quality.

In the Blue Mountains of northeastern Oregon and southwestern Washington, Quigley (1992a) said many people are expressing increased concern about the characteristics of forest ecosystems—biodiversity, old-growth, endangered species, long-term productivity, and sustainability—as opposed to only valuing short-term outputs. This is exacerbated in some forests, such as the Blue Mountains, by the forest health issue. Social and economic issues must be addressed from both short- and long-term perspectives (Quigley 1992a).

Scientific Perspectives

Forest health involves short- and long-term management considerations—treating symptoms versus curing the illness, to use an analogy with human health. Part of the problem today is not everyone agrees that forests can get sick or be made healthy. Science has little to say about the health question. Health is a matter of perception more than a matter of scientific fact. Forest health has evolved as a broader concept of forest protection than the earlier, more narrow focus. The problems of managing forests where fire, insects, and disease are parts of the ecosystem are not new problems. The approach for dealing with them must be. We must learn how to integrate knowledge accumulated by discipline-based specialists in the biological, physical, and social sciences.

Two recent forest policy textbooks did not mention forest health (Cubbage et al. 1993, Ellefson 1992). A contributed paper (Clarkson and Schmandt 1992) in an edited policy volume (Nemetz 1992) mentioned forest health without defining it. Two relatively recent forest ecology textbooks (Waring and Schlesinger 1985, Kimmins 1987) did not use the term forest health. Kimmins' (1992) popularized issue-oriented forest ecology text included a brief definition of a "healthy ecosystem" as "one in which the physical, chemical, and biological mechanisms of ecosystem recovery are operating at rates that are characteristic of that ecosystem." This definition is not only unclear, but also is a classic circular argument, and unacceptable as a biological definition of ecosystem health. It is also unacceptable because it does not address social considerations associated with ecosystem health.

Perhaps even more significant than lack of attention in recent textbooks is the almost complete omission of the term "forest health" in the National Research Council's (1990) widely discussed report, *Forestry Research: A Mandate for Change*. The 84-page report mentioned forest health only once. The report identified early diagnosis of stressed ecosystems as needing additional research funding, including as a subtopic the need "to determine the relationship between biological diversity and forest health." Although the report did not mention forest health elsewhere, it did identify several areas where increased research funding is needed for forest health subjects. This lack of recognition reflects nothing more than the new adoption of a descriptive term to represent situations that have long been recognized as real and important. To some extent it also reflects the lack of a way to objectively measure forest health and the value judgments used to define a healthy or sick forest. Both of these explain the unease of some scientists with the analogy to humans implied in the term "health."

As a research topic, the scope of forest health concerns is evolving. As a research subject class, forest health encompasses the following topics as functional subcategories, according to the American Forest and Paper Association (1993):

- Air quality/pollutants
- Integrated pest management: insects
- Integrated pest management: diseases
- Wastes
- Wildfire control
- Fuels management/prescribed burning
- Global climate change
- Overall site productivity

Forest health is a relatively new term. Smith's (1990) article on forest health in the *Journal of Forestry* is the first widespread use of the term "forest health" that we were able to locate in peer-reviewed forestry literature. The bibliography in that article is revealing because the term forest health does not appear in the titles of any cited references. Forest health has not been rigorously defined, and it has not yet been widely embraced in the forestry research community. That is likely to change. Forest health is broader than the traditional viewpoint of managing forests to bear up under the persistent wildfires, insects, and diseases that are disturbance factors in forest ecosystems. That traditional view isolated the disturbance factors of fire, insects, disease, and others for study by discipline-based scientists—entomologists, pathologists, and ecologists. Their efforts were seldom integrated. Forest health is a broader way of looking at forest conditions that goes beyond the focused concerns of single discipline-oriented science. It is appropriate that the USDA Forest Service, the world's largest forestry research organization, is leading the effort to incorporate what once was termed forest protection into the more ecosystem-oriented "forest health" terminology. There is evidence that the agency does not have adequate resources to perform this leadership role effectively. The numbers of agency scientists who perform forest health-related research have been reduced, monitoring programs authorized in federal law have not been implemented as once scheduled, and the nation's only federal installation for federal forest health research is on the east coast whereas the vast majority of federal forests are in the West. The new ecosystem management direction in the Forest Service, and the relatively new federal laws for monitoring ecosystem conditions can be approached together. Both require adequate resources. Even if the analogy of human health to forest health is imperfect, it facilitates the communication of complex subject matter to the public and to policy makers.

Sustainability will continue to present scientific problems. Scientists and managers working on forest health issues need to be sensitive to social concerns, because that is what will ultimately define sustainability. Scientists with the U.S. Environmental Protection Agency are sensitive to these issues as Riitters et al. (1990) made clear:

> The public perception of a healthy forest as one that can recover from insect infestation, disease, and other natural factors is one component of the "sustainability" value. But a term such as sustainability can have different meanings in the scientific community, and therefore it is difficult to determine what to measure. The choice of indicators, as surrogates for environmental values, defines the attributes of forest resources that will be measured.... Individuals will always have different perceptions of forests, and thus of how to describe their condition. For now,

analysts must be sensitive to these differences; ultimately, we may be able to identify a set of values that relates to everyone's perceptions of forests.

Professional Forestry Perspectives

Forests are always changing. The dynamic nature of forests makes it difficult to preserve them in one particular state or condition. Some forest conditions are desirable and others are not, in terms of meeting the aspirations of people and their need for sustainable goods and services that forests provide. The profession of forestry is changing to meet these needs.

The sustainability value is reflected in professional forestry discussions focused on maintaining the long-term health and productivity of forest ecosystems. The condition of forests throughout the nation is the cause of concern. The concept of forest health is embodied in USDA Forest Service (1988, 1993c) policy to develop a broad-based strategy for protecting forests from the effects of natural disturbances such as fire, insects, disease, and climate, and human-caused disturbances, including air pollution, fire suppression, and timber harvesting.

These concepts seem to be new because they are embedded in outcomes of policy deliberations at national and international levels, but they reflect historic concerns of how humans can interact with other organisms and the environment they share without destroying them. These are complex issues of global importance.

There are also many local issues professional foresters will be expected to address in the health context. As one example, Professor Art Partridge, forest pathologist at the University of Idaho, described "forest health" as a holy phrase for foresters akin to "diversity" or "multiple use" or "sustained yield." Based on many years of experience working with forest insects and disease, he observed that forests do not become "unhealthy all of a sudden." He said, "Forests are resilient and tend to heal themselves if allowed to do so." He warned of using forest health as an excuse for "unwarranted" salvage logging (Partridge and Bertagnolli 1993).

Bob Mutch, a USDA Forest Service fire scientist, recognized that a portion of the public has lost confidence in the ability of professional foresters to manage forests. After all, when combined with natural events such as drought, past management practices contributed to current conditions. The way to dispel perceptions of mistrust is to base management decisions on credible research results, use techniques that mimic natural processes, and involve the public in decision making (Mutch et al. 1993). This will not be easy. As journalist Ed Marston (1993) of *High County News* editorialized, "No one trusts the Forest Service to administer science-based policy."

Society of American Foresters. The Society of American Foresters formally recognized the concept of forest health on the cover of the September 1992 *Journal of Forestry* with the caption "Forest health: a cooperative effort." That issue contained three health-related articles. One article (Burkman and Hertel 1992) used the term forest health. Oliver (1992) used "environmental wellbeing" in the text of his article, but avoided the term forest health in his discussion of landscape management. Leak (1992) avoided the term forest health in a discussion of a way to measure forest productivity.

The Executive Summary of the Society of American Foresters task force on Sustaining Long-Term Forest Health and Productivity (Norris et al. 1993) was published in the July 1993 *Journal of Forestry* (1993a) and offered the following definition, which attempted to integrate ecological and management concerns: "The condition of the forest landscape is the dominant focus." As a measure of forest health, the report said: "Forests can be considered healthy when there is an appropriate balance between tree growth and mortality." Appropriate balance requires some value judgment that has yet to be agreed upon. Nonetheless, this measure of forest vegetation condition is applied to Idaho's forests (Chapter 14). We also review the potential application of other possible indicators of forest ecosystem health (Chapter 13). The task force report placed forest health and productivity in the context of ecosystems (emphasis added):

> The Task Force defines sustaining the health and long-term forest productivity to include all values and all forests, regardless of ownerships, but with attention to private property rights. Further, we emphasize managing these forests cooperatively across ownerships in large landscapes so that goods and services for human use, and ecosystem conditions such as biological diversity and ecosystem integrity, are ensured in a multigenerational time frame. Intensive forest management is a necessary part of this framework. It can be achieved within the objective of maintaining ecosystem integrity in the broad forest landscape. The report provides examples of how this might be done.
>
> Achieving this goal will require strategies that meet three criteria. Each strategy must:
>
> [a] maintain the structural and functional integrity of the forest as an ecosystem;
> [b] meet the diverse needs of the human community; and
> [c] commit the technological, financial, and human resources needed for implementation.
>
> If any of these criteria are not met, the strategy will fail or not meet expectations, and will be replaced by an alternative. Developing and implementing strategies that meet these tests will challenge the way forestry professionals think about forest resources and the institutions through which we manage them.

From the above discussion, among many other tasks it is necessary to understand what is meant by ecosystem integrity (see [a] above). This is the subject of Chapter 3. According to Woodley et al. (1993), the ill-defined concepts of "health," "integrity," and "diversity" express important values associated with resource management actions to assure "sustainability" of ecosystems. They said we need to recognize our dependence on ecosystems, not only for useful products but as an environment in which we live. However, these concepts do not provide clear guidelines for management actions (Woodley et al. 1993).

The SAF task force addressed the importance and complexity of forest health (emphasis added):

> How to sustain the health of forest ecosystems has emerged as a key challenge for the forestry profession, along with the traditional (but no less profound) questions about how to provide for the production, use, and enjoyment of forest resources.... Forest health is a particularly complex topic.... Forest health is reflected in how the forest responds or is able to respond to stress.... Forests can be considered healthy when there is an appropriate balance between growth and mortality.... Having the resilience to react and overcome various stressors is a key indicator of health, and is a key objective of ecosystem management.... [E]cosystem management is an ecological approach to forest resources management. It attempts to maintain the complex processes, pathways, and interdependencies of forest ecosystems and keep them functioning well over long periods of time, in order to provide resilience to short-term stress and adaptation to long-term change. Thus, the condition of the forest landscape is the dominant focus, and the sustained yield of products and services is provided within this context.

Conclusions

As the above excerpt concludes, the condition of the forest landscape is the dominant focus of the evolving concept of ecosystem management. Because forest health is defined as a condition of the forest ecosystem, sustaining forest health is a principal focus, if not the dominant focus, of ecosystem management.

Forest health is a multi-disciplinary concept, rarely mentioned in forestry literature before 1990. The forest health concept is based on facts and values. Until some agreement can be reached on how different values or opinions about forest health can be incorporated into objective measures, forest health judgments will remain subjective. Science cannot provide all the answers when disparate values are involved.

Some balance needs to be struck in order to advance forest health as a scientific concept, so it can perform as a useful communication tool. Part of the balance involves values that will need to come from public discussion, public policy, and the skill, judgment, and sensitivity of natural resource managers to economic and ecological considerations. Part of the balance involves facts derived from science.

Striking a balance between economy and ecology is what sustainability is all about. It is more than a coincidence that the words economy and ecology look alike. They both come from the same Greek root "oikos," or household. "Nomia" is management, thus economics is management of the household; "logos" is study, thus ecology is the study of the household. Both words connote some kind of underlying order or principles, and both approaches—management and understanding—are needed for humans and nature to coexist in the same household. That is the essence of ecosystem health and ecosystem management. Effort is needed to maintain the long-term health and sustainability of our nation's forest resources. The work to sustain healthy forests has begun.

Chapter 3. Ecosystem Integrity and Forest Health

The terms ecosystem integrity and ecosystem health have been the focus of discussion among ecologists for some time. They are not only the underpinning concepts for attempting to define, measure, and manage for forest ecosystem health, but also for developing and implementing the ecosystem management philosophy that has been embraced by the USDA Forest Service, the National Park Service, and the Bureau of Land Management. They add almost incomprehensible complexity to forest health questions, because we currently lack definitions that allow their measurement. As Jack Ward Thomas (1993) said to President Bill Clinton in April 1993 during the historic Forest Conference in Portland, Oregon, "Ecosystems are not only more complex than we think, they're more complex than we can think." He was a USDA Forest Service biologist then, and is now the Chief of the Forest Service.

In this chapter, the development and application of the concepts of ecosystem health and integrity are reviewed. Then the different perspectives of tree health, forest health, and forest ecosystem health are defined for consistent use throughout the report. The utility of analogy between human health and forest health is also discussed. This background provides necessary perspective for developing an operational concept of forest health.

Land Health

Perhaps the best place to begin developing an operational concept of "forest health" is with the writings of Aldo Leopold. A professional forester and the founder of the profession of wildlife management, he wrote in his classic essay "The Land Ethic" (1949a) that:

> A land ethic, then, reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land. Health is the capacity of the land for self-renewal. Conservation is our effort to understand and preserve this capacity.

Monnig and Byler (1992) said that by this definition, forest health is best measured by how its patterns and rates of change compare to historic patterns. This historic range of variability is a key point in making judgments about forest health conditions and will be mentioned many times in this report, and featured in Chapter 10.

Further addressing the application of health to land, in his essay "Wilderness," Aldo Leopold (1949b) wrote:

> The most important characteristic of an organism is that capacity for internal self-renewal known as health.
>
> There are two organisms whose process of self-renewal have been subjected to human interference and control. One of these is man himself (medicine and public health). The other is land (agriculture and conservation).
>
> The effort to control the health of land has not been very successful. It is now generally understood that when soil loses fertility, or washes away faster than it forms, and when water systems exhibit abnormal floods and shortages, the land is sick.
>
> Other derangements are known as facts, but are not yet thought of as symptoms of land sickness. The disappearance of plants and animal species without visible cause, despite efforts to protect them, and the irruption of others as pests despite efforts to control them, must, in the absence of simpler explanations, be regarded as symptoms of sickness in the land organism. Both are occurring too frequently to be dismissed as normal evolutionary events.
>
> A science of land health needs, first of all, a base datum of normality, a picture of how healthy land maintains itself as an organism.

Where can Leopold's "base datum of normality" be obtained to use as a standard of comparison for making judgments about health? He proposed wilderness as the "most perfect norm [with] unexpected importance as a laboratory for the study of land-health." He also proposed areas "where land physiology remains largely normal despite centuries of human occupation." This is a powerful and frequently invoked rationale for wilderness. Science has yet to measure those baselines of comparison, however.

The essence of Aldo Leopold's (1949a) land ethic is, "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." We will explore the possible use of other more technical and measurable base data for judging health conditions, because as philosophy professor Eugene Hargrove (1992) pointed out, Leopold used a nontechnical notion of land health not tied to a specific ecological theory.

Leopold provided few technical clues for determining land or ecosystem health. Instead, he provided three undefined values: integrity, stability, and beauty. Integrity, the first of these values, is now imbedded in resource management policy (Woodley et al. 1993). The second, stability, is closely associated with resilience and resistance (Costanza 1992, also see Chapter 4). Under the concept of ecosystem management, resource managers are trying to operationalize the concepts of ecosystem integrity and health. The third, beauty, is in the eye of the beholder.

Ecosystem Integrity

Since the publication of the proceedings of a 1986 workshop on ecosystem management in parks and wilderness areas (Agee and Johnson 1988), considerable attention has been focused on the concept of ecosystem management. The Chief of the USDA Forest Service (Robertson 1992) issued a directive in June 1992 that the agency will manage the national forests using ecological principles, under the banner of ecosystem management. The concepts of ecosystem integrity and ecosystem health are part of ecosystem management, which we will take up in some detail in Chapter 10. Proceedings of two workshops dealing with ecosystem integrity (Woodley et al. 1993) and ecosystem health (Costanza et al. 1992) have recently been published, and we borrow heavily from them in the remainder of this chapter.

The terms ecosystem approach, ecological integrity, and ecologically sustainable development have been used increasingly in recent years. The concept of biological integrity became a focus of public policy with the Water Quality Act Amendments of 1972 (Karr 1992, 1993). It has evolved in other policy applications to embrace ecosystems. The relevant scientific literature has suggested that none of these phrases can be easily applied in the operational sense. Indeed, ecological integrity and ecologically sustainable development are aspirations or social goals more than operational guidelines (Munn 1993).

King (1993) said an ecosystem is a diffuse and ambiguous term, but is a useful handle for referring to "that ecological stuff out there, over there" (King 1993). There are many definitions of an ecosystem. The Society of American Foresters (1983) defined an ecosystem as any complex of living organisms and their environment that humans isolate mentally for the purposes of study. Several other definitions are provided in the **Glossary**.

Definitions are only a beginning. From here, a population ecologist may focus on birth and death rates of species in the forests. A community ecologist would be interested in the distribution of species, species diversity, and resource allocation among species that leads to coexistence. The ecosystem ecologist studies how energy and matter are circulated, transformed, and accumulated in an ecosystem through the living and non-living components of the system. Ecosystem ecologists are less concerned with species diversity than the contribution of species to transfers of water, energy, and material through ecosystems at small and large scales. The boundaries of forest ecosystems are selected and defined for specific purposes of study, and used to identify and quantify the flow of materials and energy entering or leaving the system (Waring and Schlesinger 1985).

Karr (1993) defined biological integrity as the ability of an environment to support and maintain a biota or complex of living organisms comparable to the natural habitats of the region. Integrity includes both structural and functional performance. The existence of such integrity suggests that "ecological health" is being protected. This condition of health occurs when a system's potential is realized, its condition is stable, its capacity for self repair when perturbed is protected, and minimal external management is needed (Karr 1992, 1993).

The phrase ecosystem integrity is not well defined, but should have certain properties, including the ability to survive and recover from occasional severe disturbances (Munn 1993). The concept of ecosystem integrity does not seem to offer much in the way of a resource management objective. To start with, ecosystem integrity cannot be measured. King (1993) noted that we are prisoners of perspective when it comes to ecosystem integrity. Our concept of what is normal is bound to the scales with which we observe a system. For example, forest ecosystems can recover from extensive disturbance by fire or logging operations. The integrity of the system may be retained—that is, it returns to forest and not grassland or shrub—and species composition may change only slightly. However, aesthetic qualities of the system may be severely impacted. Whether or not the integrity of the forest has been compromised by the loss of aesthetics is a value judgment. The only way to deal with different perceptions of ecosystem integrity is to include indicators from as many different perspectives as practical. Those associated with human value judgments, such as economics or aesthetics, should not be excluded merely because of a prejudice for natural, ecological, or scientific perspectives (King 1993).

Kay (1993) observed that ecological integrity attempts to integrate everything known about an ecological system and where humans want that system to be in the scheme of things. The concept of ecological integrity must include societal issues and human value judgments. The normal behavior of ecosystems is complex and dynamic, and the simple notion of succession to a stable climax community is insufficient. The loss of ecological integrity does not correspond to disturbance of an ecosystem away from a climax state. Kay (1993) concluded that "A discussion of ecological health or integrity without a discussion of the social, economic, political and policy concerns is not a meaningful discussion."

Ecosystem Health

Some discussions of ecosystem health make the same points as the above discussion of ecosystem integrity. Ecosystem health is dependent on human values, just as ecosystem integrity is. Neither ecosystem health or integrity currently can be measured, so it is difficult to put either concept in a scientific context.

Rapport (1992b) observed that determinations of health hinge on human values. What is "desired" or "healthy" must ultimately take into account social and cultural as well as ecological values, which may differ among various segments of society. For example, native peoples value the integrity of the forest as a "cultural home," one that allows for traditional ways of spiritual life as well as gathering food. Some foresters value forests quite naturally in terms of productivity of merchantable timber. Consequently, the health status of forested ecosystems transformed through harvesting and other means will be assessed in very different ways depending on cultural and social values. In the ecological context, the connotation of "health" is generally conferred to a state of nature, which can be pristine or managed, that is characterized by systems integrity. But "health" ought to take into account social and cultural as well as ecological values (Rapport 1992b).

It is encouraging to realize that ecologists, economists, philosophers, and systems-oriented scientists are grappling with the concept of ecosystem health in contexts other than forests. However, their results have yet to recommend satisfactory operational approaches. Costanza (1992) summarized results of a workshop that attempted to develop operational definitions of ecosystem health. Costanza, the editor of the journal *Ecological Economics*, said the concept of ecosystem health is difficult to use because of the complex and hierarchical nature of ecosystems. In his view, ecological health represents a desired goal of environmental management, but without an operational definition of that goal, effective ecosystem management is unlikely (Costanza 1992). The idea of ecosystem health does not relieve resource managers and other interested parties from determining the purposes of managing forest resources.

Costanza (1992) said the complexity of ecosystem health may be thought of as pieces of a puzzle—absence of disease, diversity or complexity, stability or resilience, vigor or scope for growth, and "balance" between system components. No single piece is comprehensive enough for an operational definition. Instead, the concept of ecosystem health is a "comprehensive, multiscale, dynamic, hierarchial measure of system resilience, organization, and vigor," all of which are embodied in the term "sustainability." This describes the ability of a system to maintain its structure (or organization) and function (or vigor) over time in the face of external stress (resistance, resilience, and stability). A healthy system must also be defined hierarchically in terms of its context—that is, the larger system of which it is part—and its components—that is, the smaller systems that make it up (Costanza 1992). The terms resistance, resilience, stability, and sustainability are often mentioned in discussions of ecosystem health. Additional discussion of these terms as potential health criteria is provided in Chapter 4.

Tree Health, Forest Health, and Forest Ecosystem Health

For the purposes of this report, a forest is an aggregation of trees, a collection of stands of trees. A stand is a contiguous group or community of trees sufficiently uniform in species composition, arrangement of age classes, and condition to be a distinguishable unit. There is no minimum or maximum size area to define a stand (Society of American Foresters 1983, Smith 1986). A stand is the essential unit of silviculture. Forest management is primarily concerned with the forest, meaning a collection of stands administered as an integrated unit. The forest, not the stand, is the unit from which sustained timber yield is sought (Smith 1986). We make a distinction in this report between forest health and forest ecosystem health to avoid confusing the health of groups of trees (or forests) with individual trees, which is properly called tree health. Scientists approach the study of the structure, function, and physiology of individual trees differently than they do the dynamics of groups of trees, or forests. Forest health is concerned with groups of trees, not individual trees. In this report, when we want to relate groups of trees to their total environment, we will use the term forest ecosystem.

In his *Forest Ecology* textbook, Kimmins (1987) said "the management of the forest must be based on the view of the forest as an integrated ecological system or *ecosystem.*" An ecosystem includes the biological and physical environment and the dynamic interactions among biological components and environmental factors (King 1993, see the **Glossary** for other definitions).

A forest is defined by the Society of American Foresters (1983) as "an ecosystem characterized by a more or less dense and extensive tree cover. More particularly, a plant community predominantly of trees and other woody vegetation, growing more or less closely together." Because the SAF (1983) defined forestry as "the science, the art and the practice of managing and using for human benefit the natural resources that occur on and in association with forest lands," the management of forest ecosystems by definition includes all natural resources associated with forests, such as wildlife, water, and soil. These are some of the components of forest ecosystems, and the health of a forest ecosystem cannot be adequately described without consideration of a representative variety of ecosystem components.

An ecosystem is a concept, and as such is a powerful communication device (Burns 1992). An ecosystem is characterized by many things, including complexity. Forest ecosystems have many physical and biological components, and their interaction is complicated. Figure 3-1 is a conceptual model of a forest ecosystem. Scientists construct such models to measure the flow of materials or energy through the system. In this case, the arrows represent

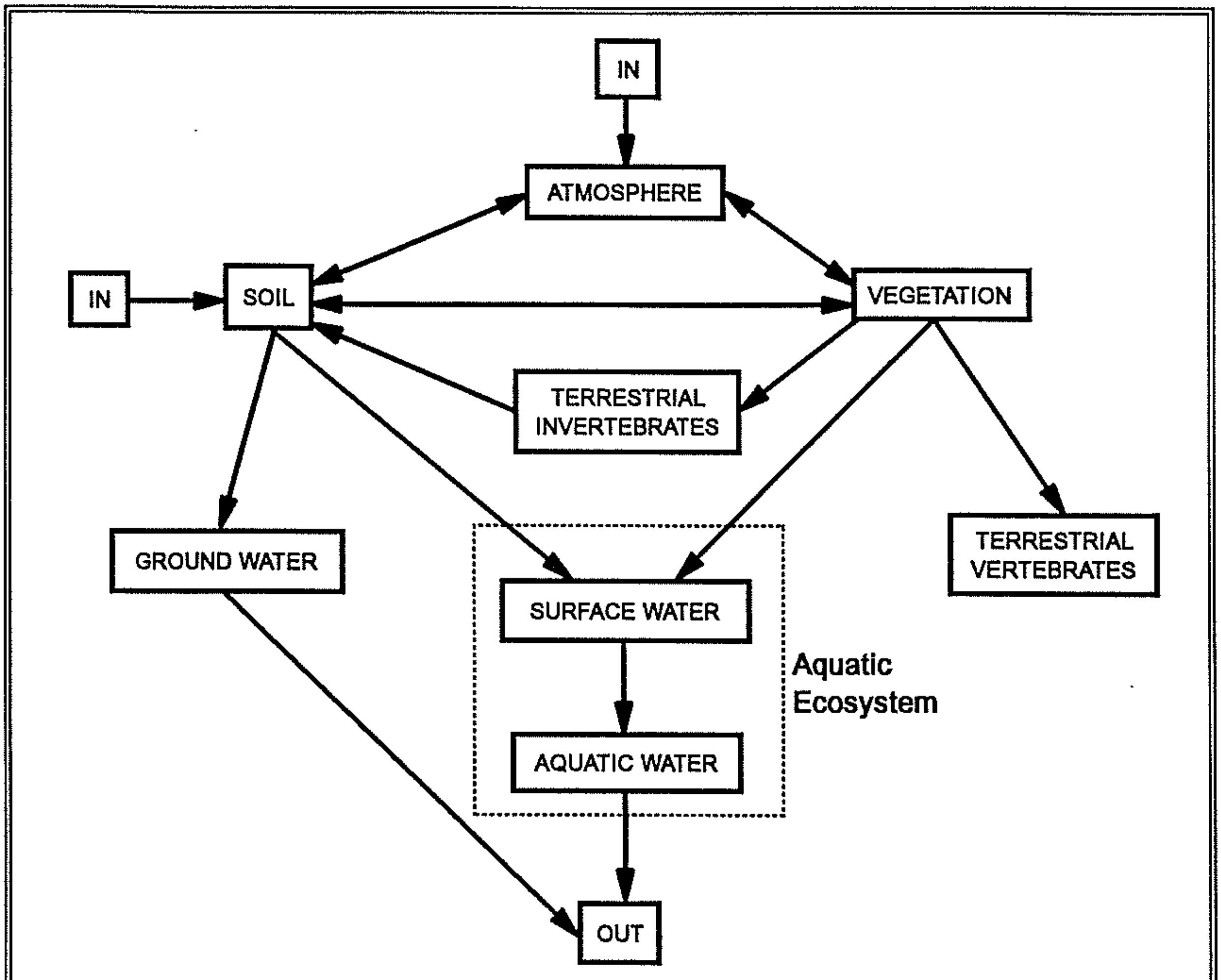


Figure 3-1. Conceptual forest ecosystem model, indicating flow of materials (water, carbon dioxide, carbon, and other chemicals).

Source: U.S. Environmental Protection Agency (Palmer et al. 1992).

flows of materials—water, carbon dioxide, carbon, and other chemicals—in and out of the system. Materials enter the system through the atmosphere and soil and leave the system through either the medium of flowing water, both underground and at the surface, or animals—terrestrial vertebrates or aquatic organisms. The key elements of a forest ecosystem are soil, water, vegetation, and animals (Figure 3-1).

The condition of a forest ecosystem depends first and foremost on the condition of trees. Without trees, there is no forest. The Association of Forest Service Employees for Environmental Ethics (Brooks 1992) recognized this point, and said "healthy trees are a reflection of the health of all parts of a forest system." A broader view would be that trees reflect the health of some parts of the forest ecosystem.

Professional arboriculturists recognize that sufficient water, suitable temperature and light, and a proper balance of nutrients are necessary to promote tree health. Too much or too little of any of these elements can lead to plant stress, which can be either acute or chronic. Disease organisms and insects commonly make matters worse by attacking an already stressed tree, compounding existing symptoms. Chronic stress is easier to treat than acute stress, including such things as improper pesticide use or untimely freezes that occur suddenly and cause immediate damage. When acute stress occurs, all that can be done is to learn from the experience and prevent its reoccurrence (International Society of Arboriculture 1991).

Forest health—the condition of a collection of stands of trees—is more complicated than individual tree health. Professor John Marshall (1993), a tree physiologist at the University of Idaho, pointed out that trees are individual organisms. Forests are not, and forest ecosystems emphatically are not, individual organisms. Individual trees in any stand will exhibit substantial variation among them. Furthermore, individual trees compete with one another. Unlike the parts of an organism, there is no reason to expect coordinated behavior from individual trees in a stand. If the least vigorous trees in a stand die, the condition of others in the stand may be improved through reduced competition (Marshall 1993).

Ecosystem components are interdependent and some of these relationships are essential for the normal functioning of the other parts. The wise forester will remember this before making major changes in the ecosystem (Kimmins 1987).

Kolasa and Pickett (1992) observed that scientists are properly wary of ecosystem health because arbitrary diagnoses can be challenged on various scientific, philosophical, or political grounds. The hierarchial nature of ecosystems makes assessment of relative stress and health conditions difficult because both states may occur simultaneously at different levels in the ecosystem hierarchy. Stress at one level may be a necessary condition of health at another. A sensible notion of ecosystem health is the persistence of the system within a given temporal or spatial scale. This does not address the relative desirability of components in the system structure from a human point of view. A changed ecosystem may be considered healthy by some people and unhealthy by others (Kolasa and Pickett 1992).

Forests, whether viewed as aggregations of individual trees or as ecosystems, are complex. Complexity confounds scientists, who need to simplify real world complexity in order to measure and model the way things work. Complexity, however, is no excuse for management inaction. Because of the many benefits people derive from forests, it is in the best interests of society to maintain forests and forest ecosystems in productive and functional states. Regarding the benefits people want from forest ecosystems, it matters little if the condition that promotes these values is called health, integrity, sustainability or something else altogether.

Is Human Health Comparable to Forest Health?

The health of the human body offers a useful but limited analogy to forest ecosystem condition. The comparison of ecosystem health to human health can provide useful analogies, as human health is similarly undefinable. Managing for health involves not only treatment of the symptoms, but also preventative actions to reduce future disturbances or disruptions of system function. Kimmins (1992) observed that unlike the human system, which inevitably must die, a forest ecosystem will not die as long as its recovery processes are not destroyed. Professor Mlinsek (1991) of Slovenia was even more blunt: "Trees die but forests never do."

Forest health may be thought of as comparable to the public health model in the study of human health. Public health deals with characteristics of human populations, including birth and death rates and understanding of why epidemics arise and how they can be suppressed and prevented. These ideas have already been imported into forestry and also are at the core of managing fish and wildlife populations (Marshall 1993).

In the end, noted Rapport (1992a), metaphors drawn from human health and applied to ecosystems must cope with three fundamental dilemmas: [1] no strictly objective criteria exist for judging health, even in the case of humans; [2] nature has an irregular pulse that either precludes early recognition of system changes or gives rise to false alarms; and [3] indicators that represent the system need the attributes of being holistic, early warning, and diagnostic. Indicators that excel in one of these aspects often fail in another (Rapport 1992a). At the ecosystem level, the search for such indicators is only beginning (see Chapter 13).

Calow (1992) noted that the purpose of drawing analogies is usually to further an understanding of the unfamiliar by reference to features of the familiar. The health of organisms and populations of organisms can be understood objectively, but similar reasoning cannot be applied to ecosystems (Calow 1992). The concepts of stress and health were developed for organisms. When extended to the ecosystem level, there are risks of misunderstanding, mismeasurement, and confusion. This is partly because the concept of ecosystem itself needs refinement (Kolasa and Pickett 1992). But the analogy moves the almost incomprehensibly complex idea of relative condition of ecosystems into an understandable context.

Once again the ideas of Aldo Leopold (1949a) have been instrumental in developing the concept of forest health as related to human health:

> In general, the trend of evidence indicates that in land, just as in the human body, the symptoms may lie in one organ and the cause in another. The practices we now call conservation are, to a large extent, local alleviations of biotic pain. They are necessary but they must not be confused with cures. The art of land doctoring is being practiced with vigor, but the science of land health is yet to be born.

As Leopold drew the analogy, he urged the development of a new science of land health. Forty years later, his call is now being answered, and existing knowledge is being looked at in a different and broader context, and new research problems are being formulated. Burns (1992) noted that few if any scientists recognize land or land-based ecological systems as organisms. Nonetheless, Leopold's challenge is compelling.

Costanza (1992) identified the limits of the analogy in the general ecosystem context, as have others. Rapport (1992b) said concepts of ecosystem health can be derived by analogy with concepts of human health. Both are complex systems composed of interacting parts with interdependent functions. But Schaeffer and Cox (1992) pointed out that humans are warm-blooded systems, and human physicians have developed a compendium of known diseases, a wide body of reference data on "the standard human," and many diagnostic tools. None of these aids are available for ecosystems (Costanza 1992).

In the forestry context, Publicover (1987) said foresters present themselves as "doctors of the forest, wiping out disease and leaving a forest healthier" as a result of their intervention. He pointed out that the public is skeptical of forest management and reveres wilderness, designated or undesignated, as ecosystems that function as they always have. He said, "The public sees these areas as a doctor sees healthy skin on a severely burned patient. Yet foresters think of unmanaged forests as diseases in need of a cure." He urged his fellow foresters to get rid of this attitude if they hope to regain credibility with the public.

Where did the idea of foresters as administrators of forest health arise? It began with Leopold and took a while to sink in, or at least to surface in forestry literature. Waring (1980) was one of the first scientists to compare forest ecosystems to the human body. Both are complex systems, composed of many parts carrying on various functions that are essential to the well-being of the whole. A mutual concern is when functions necessary for long, productive lives become impaired. As Waring (1980) said, because forests "provide irreplaceable services, when these systems are threatened, we must administer aid." This implies some type of management.

Smith (1990) compared forest stress to human cancer. There are no easy solutions to either problem. Smith defined stress as any environmental agent (biotic or abiotic) capable of inducing an abnormal physiological effect in trees. Tree or forest decline is the widespread decrease in the health and vigor of a tree or group of trees due to disease or injury. The study of human cancer is a useful analogy for studying forest decline phenomena. Cancer has multiple stages, and some cancers involve multiple stress interactions. The current limited capabilities of toxicology make it impossible to confidently assess the relative importance of specific factors involved in certain cancers. Similarly, the current capabilities of forest science are frequently unable to assess confidently the specific factors involved in wide-area forest decline phenomena (Smith 1990).

For example, it is difficult to assign causes to observations of forest decline at higher altitudes in the eastern United States. Observed mortality could be a consequence of acid precipitation, but changes in forest growth patterns integrate so many other factors, including stand conditions and natural succession, that precisely defining the contribution of any single factor is difficult (King 1993).

Until we become serious about long-term forest health assessment, we will not know whether the health of forest systems is improving, stable, or declining. Physicians routinely measure body temperature, blood pressure, heart rate, and weight to monitor general fitness. Forest scientists have comparable parameters for tree and forest health: annual height growth, live crown ratio, leaf area, and needle retention for single trees; and leaf area, diversity, dominance, and productivity for forest stands (Smith 1990).

Space (1992) drew a parallel between forest health and human health. He said the modern thinking on human health is to prevent problems before they occur by adopting a healthy lifestyle, rather than diagnosing and treating problems as they occur. He envisioned the same approach to forest pest management—develop and maintain healthy forests by managing them on "sound ecological principles" and preventing problems before they occur.

Byler and Zimmer-Grove (1991) used a similar analogy. Medical professionals have shifted human health care from the traditional emphasis on treatment of illness with medicine towards "wellness." Our lifestyle may contribute more to our health than do genetics, environment, and health care, important as they are. Proper diet, regular exercise, and other personal habits have a greater effect on our well-being than does treatment of illness. Furthermore, knowing what behavior puts us at risk allows us to reduce the risk by modifying our behavior.

Conservation needs have been described with the same analogy. Barnard (1992) said that in order for the Forest Service to meet its motto of "Caring for the Land and Serving People" the agency must know the health of the land and its resources, just as physicians must know the health of their human patients. To nurture forests to better serve people, the agency must know the current ability of the forests to meet people's needs—that is, the agency must monitor the health of forests. Miller (1991) suggested that forests need regular checkups, analogous to annual physical examinations.

Kimmins (1992) also used the analogy of human health and forest health. He said all living systems have inherent powers of recovery. Forest ecosystem processes enable ecosystems to resist changes in their form and function. Unless the recovery mechanisms have been damaged, they can recover relatively quickly from disturbances—that is, they are resilient. But these recovery processes can be damaged. For example, humans with defective immune systems, such as AIDS sufferers, can die from relatively mild infections. If a disturbance destroys or impairs the processes of recovery in a forest, the impact of subsequent disturbance can be very persistent. If the processes of recovery are allowed to operate, ecosystems will always at least partially recover from even severe disturbances (Kimmins 1992).

Even though the concept is fraught with problems, it has become popular to speak of ecosystem health and compare it by analogy to human health. Haskell et al. (1992) said the process of defining ecosystem health has begun, and they proposed to use the practice of human and animal medicine as the model for the practice of "ecological medicine." That practice would follow this sequence:

[1] Identify symptoms.
[2] Identify and measure vital signs.
[3] Make a provisional diagnosis.
[4] Conduct tests to verify the diagnosis.
[5] Make a prognosis.
[6] Prescribe a treatment.

This model of health assessment can be applied to ecosystems, but ecologists do not have a compendium of known diseases or stresses with associated symptoms and signs as do medical practioners (Haskell et al. 1992).

According to Rapport (1992b) attempting to determine nature's health by measuring exposure to stress is as inadequate as reading human health by exposing a person to disease. It is not only exposure but also the innate characteristics of resistance or susceptibility possessed by the individual or ecosystem that determine the outcome. Thus health status can be confirmed only by clinical investigation.

Measuring nature's pulse is illusory. For most natural systems, there is scant likelihood of discovering a function even remotely equivalent to the pulse in human medicine (Rapport 1992b). The ratio of the rate of photosynthesis to respiration has been suggested as a measure of forest condition (Bormann and Likens 1979). Most ecosystems might be characterized not by regularity, but by arrhythmia—that is, by highly irregular dynamics punctuated by surprise (Holling 1986). For example, the boreal forest and other perturbation-dependent ecosystems (Vogl 1980) exhibit complex dynamics with substantial fluctuations in primary production, species composition, nutrient loads, and insect pest levels (Rapport 1992b).

Medical diagnosis is frequently a matter of perception, which is why second opinions are encouraged. One doctor may say a person appears healthy, another may say the person is seriously ill. "Looking" healthy remains an important guide that may either encourage or discourage medical treatment (Hargrove 1992). The same may be said of forests. Some people will look at a particular forest and say it looks sick and needs treatment. Others may not come to the same conclusion. Even if people may agree that a forest is sick, they may disagree for various reasons about the treatment.

Conclusions

Ecosystem health and ecosystem integrity are related concepts that underpin discussions of forest health and ecosystem management. However, neither ecosystem health nor integrity are measurable concepts, making scientific discussion difficult. Both concepts are matters of human perception and value, and both are part of what everyone desires: sustainable forest ecosystems.

Health offers the advantage of being comparable to something we understand, making the integrated holistic view of forest protection concepts easier to communicate to the public. The notion of health captures the attention and imagination of people, inspiring them towards solutions for avoiding unhealthy conditions.

Chapter 4. When is a Forest Healthy or Unhealthy?

When is a forest healthy? There is only one correct response—it depends. It depends on individual perceptions of what a forest is, as well as what the term "healthy" means, how health is measured, and where the dividing line is between healthy and unhealthy. The idea of "looking" healthy depends on what one is looking at, and the frame of reference one is using.

In this chapter we examine some of the more common terms and ideas that are used to denote healthy or unhealthy forests. Forests change and some changes are considered undesirable or unhealthy by some people. The words catastrophe, epidemic, and holocaust are sometimes related to changes in forest structure and function. The idea of naturalness as a benchmark criterion for forest health is discussed, including the "balance of nature" and "nature knows best" arguments for management direction. The forest health goals of resilience and sustainability are also examined.

The achievement of forest management objectives, or the attainment and maintenance of fully functioning forest ecosystems, involves two different approaches to solving forest health problems. The one deals with social, economic, and political determinations as to the purpose or uses of a forest, usually within physical or biological constraints. The other directs biological science to determine that purpose. The two approaches come together with the emerging concept of managing ecosystems. Our state of knowledge of the relationships of forest ecosystem components can be described as the condition or "health" of a forest, and thus provide either some ecological constraints on forest uses, or a determination of purpose, such as a sustainable ecosystem.

The identical preface appearing in two reports on forest health in the Blue Mountains (Quigley 1992a, Wickman 1992) sets the stage for a science-based discussion of forest management issues:

> The Blue mountains of northeast Oregon and southeast Washington are composed of a complex mix of ecosystems, habitats, landforms, and economies. Several consecutive years of drought, epidemic insect infestations, and catastrophic fire are threatening the natural resources and the social and economic systems within the Blue Mountains. The general health of the forests is not good and may be worsening. A primary factor leading to the current deteriorated condition has been the exclusion of fire. Past timber management practices also have contributed.

As in the above quotation, insect and disease outbreaks are commonly described as "epidemic." Similarly, wildfires are quite often described as "catastrophic." Are these terms mere hyperbole—as at least one environmental group, The Wilderness Society, believes (Aplet 1992)—or do they accurately describe current situations? Although these terms have some scientific basis, as we will show, the words of Vance and Wilson (1990) are instructive:

> What we call "disasters" are a part of life, for the environment as well as for humans. Holocaustic fires, massive oil spills, volcanic eruptions and earthquakes have alarming consequences. But are they always disasters? It is instructive that in Chinese philosophy, crisis is also regarded as opportunity. Great environmental disasters may provide opportunities not only for nature, but for scientists as well. In the past, the temptation for scientists has been to treat unexpected cataclysmic events as interesting but extraneous, best ignored as deviations from the norm. Now scientists are recognizing that we cannot afford to neglect these events and their ecological effects. Infrequent but massive environmental changes caused by disasters create patterns of ecosystem recovery that often redistribute species, set the productivity of forests and fields, and reshape the landscape.
>
> How do natural systems respond to such major disruptions, and how are natural ecological processes altered not only by the disturbance, but also by human intervention?

The above questions posed by Vance and Wilson (1990) are relevant to forest health conditions in Idaho. To begin to reply to them, it is necessary to define some terms. Agee and Johnson (1988) made a similar point in reference to an important ecosystem management research need—the identification of thresholds of change in key ecosystem elements and their relation to management strategies.

Catastrophes and Epidemics

"Catastrophic" fire. Definitions of catastrophe usually include the word "disaster" (Random House 1971). This is unfortunate, because the etymological root of catastrophe is translated from Greek as "overturning." In this context, catastrophe appropriately describes the effects of some fires. These effects are closely allied to the dictionary definition of catastrophe as "a sudden, violent disturbance, especially of a part of the surface of the earth; cataclysm" (Random House 1971). Whether a catastrophic fire is a disaster, however, is a judgment based on values, not science.

A "holocaustic fire" may be another matter. The dictionary definition of holocaust is "a great or complete devastation or destruction, especially by fire, from the Greek 'burnt whole'" (Random House 1971).

Fire has immediate and long-term effects on species, communities, and ecosystems. The effects depend on fire severity, extent, and timing, and on the type of vegetation. These in turn are functions of climate, soil, topography, and fire history. Although variation in both fires and their effects is almost infinite, two general forest fire regimes are recognized (Barney et al. 1984):

> [1] *Stand-replacement fire regime*—mostly moderate- to high-intensity ("catastrophic") fires, including considerable crown fire occurring at long intervals, 50-500+ years; practically all vegetation killed to ground; most surface fuel and varying amounts of crown fuel (living and dead) consumed; fallen, fire-killed material becomes serious fuel hazard for several decades after fire; regeneration and redevelopment of the entire stand takes place, radical change in species composition possible; successive burns at short intervals may convert to fire-adapted tree species or to brush; ecosystem is a patchwork of stands of different ages and compositions; typical of short-needled conifer forest, for example, the boreal forest, Douglas-fir region.
>
> [2] *Stand maintenance fire regime*—mostly low to moderate intensity surface fires at short intervals, 2-25 years; subordinate vegetation variably killed back; small to moderate amount of surface fuel consumed; little or no accumulation of fire-killed material, fuel hazard is reduced temporarily; subordinate vegetation regenerates, with some changes in relative abundance of species; ecosystem comprises an essentially uniform, possibly all-aged stand of dominants over varying age classes of subordinate vegetation; typical of long-needled conifer forest, for example, ponderosa pine, longleaf pine, grassland, savanna.

The most severe category of catastrophic fire, called "holocaustic" fire, is defined by Stickney (1990) as a fire that incinerates all of the finer fuels on a site. Its characteristics in the Northern Rocky Mountains are:

> [1] destruction of the coniferous tree overstory, [2] reduction of the tree-shrub understory and herb layers to the ground level, and [3] conversion of the dead organic mantle of the forest floor to ash down to the mineral ground surface. Although this fire treatment incinerates the above-ground portion of the forest community, the below-ground portion can remain intact and essentially undisturbed.

"Catastrophic damage". As defined in the Blue Mountains Forest Health Report catastrophic damage is said to occur when management goals and objectives are significantly impaired (Gast et al. 1991, see the **Glossary**). This definition used by the USDA Forest Service is more vague than an earlier one. Before he served as Chief of the Forest Service from 1972 to 1979, John McGuire (1958) defined "catastrophic" timber mortality as follows: "Losses are considered catastrophic if the individual occurrence resulted in an annual mortality greater than net annual growth of the affected State or region." This definition becomes relevant in Chapter 14 when we analyze forest conditions in Idaho.

Insect and disease "epidemics". Insects and disease pathogens are generally considered to be forest pests. Unless introduced as exotic pests, they are natural components of forest ecosystems that exist as endemic populations and, as Haack and Byler (1993) pointed out, perform natural regulatory functions.

Forest pest epidemics occur when natural limiting factors are altered and endemic populations increase to abnormally high levels. These naturally limiting factors include, but are not limited to, the following (L. Livingston, review comments): [1] reduced numbers of natural enemies, [2] escape of the pest organism to a new area where natural controls are not present, [3] rapid and extensive creation of a food base, which can result from many factors, including timber harvesting and slash accumulation, fire, drought, high temperature, windthrow, defoliation, and stagnation of growth.

There are no standard indicators of when a forest pest problem exists. For defoliating insects, an endemic condition exists when defoliation is not observed by aerial detection surveys (L. Livingston, pers. comm.). A rapidly expanding population is an indication of epidemic conditions for western spruce budworm (D. Ferguson, pers. comm.), but generally only if defoliation occurs (L. Livingston, review comments). Douglas-fir tussock moth populations are monitored in Idaho by observing the number of moths captured in traps. A capture rate of 25 moths per trap triggers more intensive and extensive monitoring; however, capture rates do not necessarily indicate the intensity or type of control activity that may be implemented.

Bark beetles are always in the forest at endemic levels. A low level of activity is indicated by single or small groups of trees with yellowing foliage. When observers detect more than "normal" amounts of foliage change, epidemic or potential epidemic populations are at hand (L. Livingston, pers. comm.; B. Bentz, pers. comm.).

Whether or not these conditions indicate that a problem exists depends on management objectives. Lands managed primarily for timber production can only tolerate low levels of tree damage. This might not be the case for lands managed primarily for non-timber objectives. However, even on industrial timberlands in Idaho, specific guidelines related to forest health do not exist, but efforts are underway to initiate more systematic and intensive monitoring of pest conditions (J. Olson, pers. comm.).

The Nature of Nature

Political scientists Cawley and Freemuth (1993) observed that nature has played a privileged role in political discourse for some 300 years. Although nature is generally presented as an objective foundation upon which political judgments can be based, in political discourse nature is a "metaphor carefully crafted to defend a predetermined prescription regarding the appropriate character of political order" (Cawley and Freemuth 1993).

"Naturalness" as a criterion. Philosophers and scientists as well as political scientists, have struggled with the idea of nature as a criterion for judging various metaphysical and physical relationships. If we could achieve some agreement as to how the idea of "naturalness" applies to forests, we would be well on the way to resolving some of the more contentious issues about forest management. Of the several dictionary definitions of nature, some would choose a universal definition that encompasses all the phenomena of the universe, including humans. Others would choose to exclude humans from their definition of what is natural. The argument is deeply philosophical and at the root of most forest resource management issues, including forest health.

Sagoff (1992), a philosopher, said the concept of ecological health or integrity cannot be defined in terms of ecological "authenticity"—that is, the natural realm cannot be meaningfully separated from human cultural history. He said the concept of health must be compatible with the cultivation and use of nature, and that humans may need to conceive of nature not just as a collection of resources or materials for use but instead as the habitat or place where they live. By preserving the health and integrity of other species and ecological communities, humans sink their roots in the land they inhabit and become native to a place (Sagoff 1992).

Callicott (1992). also a philosopher, said change is natural, human beings are a part of nature, and human-caused changes are no different from other natural changes. Some changes may be bad and others good, but without objective norms of ecological health, such evaluations of human modifications of the landscape cannot be made (Callicott 1992).

Some people will insist that nature is the appropriate ecosystem model, because they believe that nature knows best. Even if one were to concede that this is so, there would be problems operationalizing this notion as a scientific guide to resource management. As Calow (1992) said, "To make sound predictions about what properties would be expected of undisturbed ecosystems will require progress in fundamental as well as applied ecology." Anderson (1991) suggested some starting points for scientifically evaluating and quantifying naturalness.

Aldo Leopold promoted the idea of using undisturbed ecosystems as benchmarks. Ecologists have not yet figured out how to do that, for the reasons discussed in the next two sections.

Does nature know best? Forest scientists lack complete knowledge of how forest ecosystems function, just as physicians lack complete knowledge of how the human body functions. Yet when we become ill we expect treatment based on what medical science does know. Because we lack complete knowledge, should we do nothing until we know everything about a particular ailment or health situation? Some people think so when it comes to managing forests. They believe nature knows best.

Some representatives of environmental groups have expressed doubts that forest health is an appropriate management objective, particularly if it involves logging, even if trees are dead or dying. Their concern is that the cure may be worse than the disease and that nature knows best how to cure ailing forests (see Blatner et al., 1994). In medical science, a similar idea is called therapeutic nihilism. According to Hargrove (1992), this was a form of medical practice in the mid-19th century where doctors concluded that the limits of medical knowledge had been reached and that treatment of a wide range of illnesses actually reduced patients' quality of life and sometimes seriously endangered their lives—that is, the cure was worse than the disease (Hargrove 1992).

Hargrove (1992), philosopher and editor of *Environmental Ethics*, refuted the idea that "nature knows best." He said the notion of therapeutic nihilism found its way into professional environmental management when problems with the scientific management of natural systems arose in the 1930s and '40s. One example he gave was the deer irruptions on the Kaibab plateau that led Aldo Leopold to develop some of his ecological ideas. Therapeutic nihilism, or nature knows best, is embodied in the National Park Service policy of "natural regulation." It is also a belief commonly held by most environmentalists and the general public. At the popular level, environmental therapeutic nihilism is known as Barry Commoner's third law of ecology, often invoked in nature preservation arguments, that any major manmade change in a natural system is likely to be detrimental to that system. The general public widely and uncritically accepts this so-called law. Many environmentalists employ it as a criticism of professional ecology where "attempts by ecologists to solve problems within natural systems are comparable to—and no more effective than—random thrusts into the works of a watch by a person with no knowledge of watch repair" (Hargrove 1992). Sometimes this value-based "law" is presented as a factual claim that ecologists do not have, and will never have, the knowledge to manipulate natural systems without creating unanticipated disruptions. Thus, said Hargrove, therapeutic nihilism allows environmentalists to "avoid discussion of environmental values because it can be presented as a factual claim that policymakers tend to respond to more favorably than to value-based arguments." Hargrove (1992) concluded his point, as one might expect a philosopher to, with the lament that values have come to be viewed as subjective, arbitrary, irrational, emotional, and meaningless.

Some people believe as a matter of principle that nature knows best. They believe that an ecosystem free of human intervention will take care of itself, as if this were a principle or law that should be adhered to. Smith (1993) observed that some people see nature as God, rather than a creation of God, causing them to reject science and view resource management as a desecration of the sacred.

Burns (1992) pointed out that it is appropriate for accepted principles of ecological science be part of the discipline. But he said ecological principles

> may have little bearing on human society's ability to face future challenges. Towards this end, the power of the ecosystem concept lies in it being a concept, as opposed to a principle. Concepts are more powerful than principles. Concepts condition our thinking and evaluation of alternatives. They are flexible (fuzzy, vague, imprecise) and expansive (general). They are rich in meaning and implication. They can be communicated more easily to a greater diversity of people. They can be related more naturally and easily to folklore and common knowledge. What is more, they can embody the values of those who are able to conceive them. This may make them unscientific compared to principles, but it does not reduce their truth content. More importantly, it is the source of their power, because real change in man's relationship with nature will require prescription by citizens, not description or prediction by ecologists.

Burns (1992) had an inclusive view of ecosystems; humans, he said, are part of ecosystems, from the "backyard to the biosphere."

Does nature know best? Nature and "natural regulation" provide what some people desire from a forest, but not necessarily everyone. In this context, ecologist Daniel Botkin (1993a) said, "When you do nothing, you'll get something you didn't expect." That unexpected something may or may not be what people want.

The "balance of nature." Although the notion of a "balance of nature" has popular appeal, its scientific basis is weak.

Ecologists no longer apply the concept of a "balance of nature" and its implied equilibrium state (Kaufmann 1993, Stevens 1991). There are two reasons why. First, the notion of "balance" implies a steady-state equilibrium of system components. Ecologists have demonstrated that disturbance and subsequent recovery are integral processes in many ecosystems (Ehrenfeld 1992), and that the endpoint of a climax stage is never achieved. Even if it is, a climax is not a steady or stable state. Furthermore, Waring and Schlesinger (1985) said, "A forest ecosystem is never in equilibrium, a term appropriate to closed systems in the laboratory. Only the entire globe exists as an equilibrium system, and then only for materials and not for energy." The "balance of nature" does not exist in science or nature except in small areas, over short time periods, and among a small portion of the components of an ecosystem.

Second, the terms nature and naturalness are confusing (Götmark 1992). The dichotomous views of the relationship of humans to nature leads to non-scientific problems. Some people insist that humans are part of nature, others are adamant that human influence should be excluded from what is natural. Science cannot determine which viewpoint is correct, but many scientists believe there are no longer any parts of the earth that have not been affected by humans (Kaufmann 1993).

Yet the term "balance" is one of the most widely used terms in discussions of natural resource management and policy. Balance implies equilibrium, but ecosystems are dynamic, exhibiting patterns of disturbance and recovery rather than a steady state. The term "balance" can be useful nonetheless to describe the relationship of ecosystem components or characteristics. To some scientists, insect populations at epidemic levels indicate a system out of balance.

Byler and Zimmer-Grove (1991) said the justification for a forest health strategy is based in ecological theory, as is integrated pest management. They use the term "biological balance" to describe the relationship that develops between pathogens, their hosts, and the environment in "natural ecosystems." Ecologists once described this as an "ecological balance" or "balance of nature." The relationship is dynamic and fluctuates over time as ecosystems change. Byler and Zimmer-Grove cited Aldo Leopold (1933), who said actions that upset that relationship or ecological balance may bring unpredictable and undesirable changes, which may be irreversible. However, in his essay "The Land Ethic" Leopold (1949a) refuted the notion of the "balance of nature":

> The image [of land as a biotic mechanism] commonly employed in conservation education is "the balance of nature." For reasons too lengthy to detail here, this figure of speech fails to describe accurately what little we know about the land mechanism.

Nonetheless, the idea of the "balance of nature" persists in discussions of ecosystem management. Costanza (1992) attributed this to the tradition in Eastern medicine that a healthy system is one maintaining a proper balance between system components. This idea is part of ecological theory and used to explain the distribution of system components—for example, "the ecosystem is in balance"—rather than in a predictive or diagnostic manner. The problem, according to Costanza, is that we can't know if the system is out of balance unless we have some overall indicator of health to use in making such judgments.

The last fifteen years of ecological research and thought have provided a steady extension of the role of natural disturbance in the life of communities and a corresponding erosion of the normative view of community organization and function (Ehrenfeld 1992). This is the "new ecology" described by Kaufmann (1993) and championed by Botkin (1990). The ideas of "new ecology" refute the notion of a balance of nature. These ideas are really not very new. Ecologist Charles Elton (1930) said, "the balance of nature does not exist, and perhaps has never existed." "New ecology" eliminates the qualifier "perhaps" from Elton's statement.

"New ecology" refutes the concept of an equilibrium balance of nature, because disturbance and resultant change is a fundamental characteristic of ecosystems and change is largely unpredictable. The ideas of "naturalness" and "new ecology" were applied to park and wilderness ecosystem management at a workshop at the University of Washington in 1986 (Johnson and Agee 1988):

> Considerable confusion has resulted from a widespread misconception of the dynamics of ecosystems.
>
> Such systems are envisioned as having a natural balance or static equilibrium that in fact does not exist....A "balance of nature" occurs only over short and constrained periods: the constant in these systems is change. This fact is fundamental to establishing realistic goals for park and wilderness management....The word "natural" remains difficult to define because it incorporates value judgements that cannot be scientifically resolved.
>
> If natural process management is assumed to be an evolution free of human influence, implementation of natural process management...will be difficult to accomplish....The concept of natural systems remains viable, but only in a dynamic and flexible context. Change, and sometimes unpredictable change, is essential to the natural systems concept....Natural resources management, including park and wilderness management, is an experiment. We simply do not know precisely the outcome of most management strategies. Many of our goals will therefore be achieved through hypotheses that are continually tested and refined. Two common themes emerge through these strategies. The first is that people are a part of the management solution....The second theme is that because 'naturalness' is subjectively defined, park and wilderness preservation goals will have to be stated in more precise system-component terms depending on the values represented by the individual area (Johnson and Agee 1988).

Ecologist Daniel Botkin is a leading proponent of the ideas of new ecology. In his book *Discordant Harmonies* (1990), he said more knowledge about nature is necessary, indeed essential, for humans to achieve harmony with the natural systems and environment. In most areas we don't have even the most basic information about the condition of nature. He said an understanding of nature needs to replace the mere appreciation of nature. That understanding, based on Botkin's decades of research, is that disturbance is natural, and more emphasis should be placed on its role in nature rather than the elusive quest for the balance of nature epitomized as constancy and stability. Because of this, he said we should reject the notion that nature knows best and that somehow human understanding is irrelevant to management. He said we should cease analyzing and managing ecosystems as if they were machines full of gears and wheels, for which our goal is a steady-state operation (Botkin 1990).

Kimmins (1992) said all forests are disturbed periodically and are always undergoing change, thus reinforcing Botkin. Disturbances can be either the small-scale death of individual trees, or large areas of trees being killed by insects, fire, or wind. The disturbance is sometimes frequent and sometimes infrequent. Regardless of the temporal or spatial scale of disturbance, monitoring over at least several decades, and in some instances centuries, will reveal that some patterns of forest change are human-caused and others are not connected to human activity. Judgments whether human activity has reduced the "sustainability of the forest ecosystem" involve a comparison between the observed pattern of ecosystem change and the pattern of change expected for a "healthy ecosystem." Kimmins (1992) defined a healthy ecosystem as "one in which the physical, chemical, and biological mechanisms of ecosystem recovery are operating at rates characteristic of that ecosystem."

Resistance to the ideas of new ecology is strong among environmentalists and commodity interests alike. For example, environmentalists assert that the balance between forests and salmon in Oregon has been destroyed; industry representatives assert that a balance will reestablish itself. Botkin is studying the situation, and observed that not enough information exists to support either claim. According to him, not enough is known about the life cycles of salmon, nor are there reliable data on the extent of regeneration in forests that are being lost "forever." He says the important thing is to focus attention on rates and magnitude of change in these system components, with the understanding that certain changes are natural, desirable, and acceptable, and others are not. But as long as we refuse to admit that change is natural, we cannot make such distinctions and deal with the implications (Kaufmann 1993). In the end, said Botkin (1992), "acceptance of the naturalness of change is the only way to come to harmony with nature."

Health Goals

The degree of change and the mechanisms of ecosystem recovery following disturbance are an important part of ecosystem health (Kimmins 1992). This concept encompasses the ideas of resistance and resilience, stability and sustainability. These concepts are not easy to explain, but we will attempt to in this section.

Resistance, resilience, and stability. Resistance is the opposition to change in ecosystem processes due to a disturbance. This is illustrated in Figure 4-1 by the vertical deviation of ecosystem function below the "normal operating range." Resistance is interchangeable with amplitude stability—the extent to which an ecosystem can be changed and still return rapidly to its original condition (Kimmins 1987). A system altered beyond its limits of resistance will return to a new community domain with a different composition and functional interactions of species.

Resilience is the rate at which an ecosystem's composition returns to the point at which the community processes and interactions function as they did before disturbance (Holling 1973, Pickett and White 1985). Vogl (1980) reviewed numerous studies of recovery times for ecosystems under natural stress. It is from this that the notion of

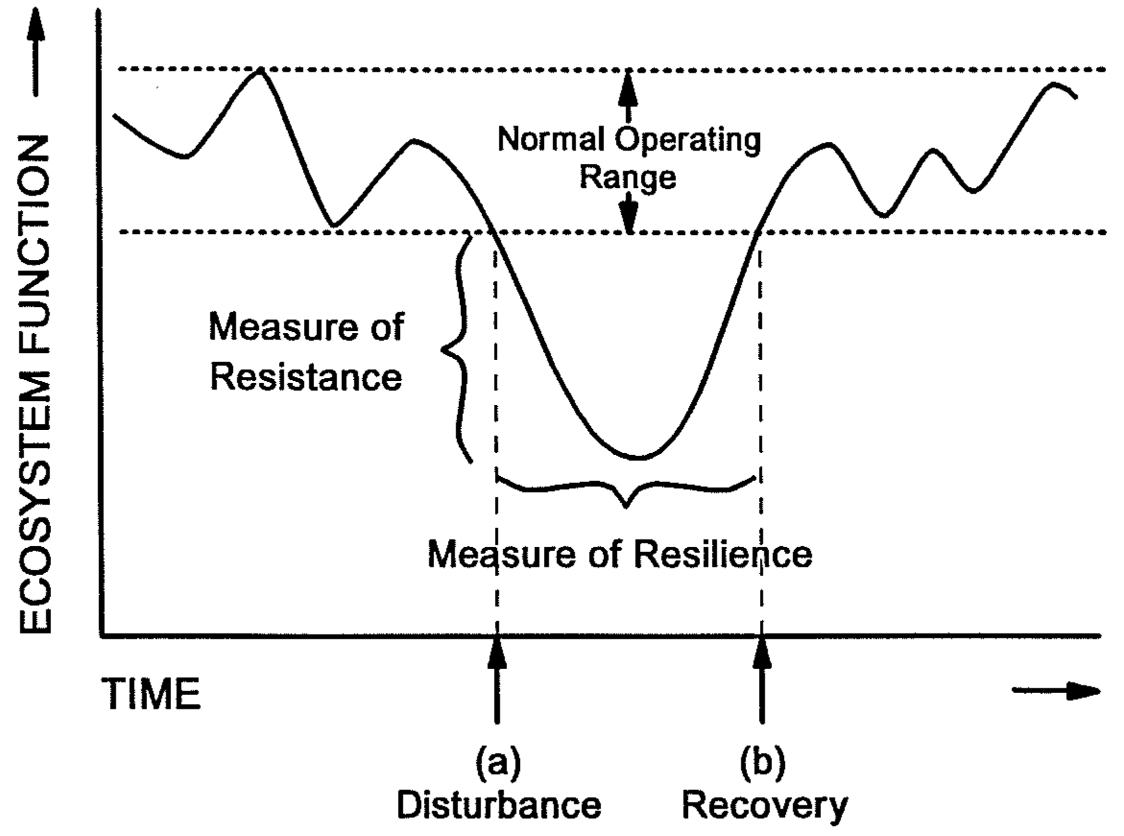


Figure 4-1. Resistance and resilience—two related concepts of ecosystem stability.

Source: Adapted from Odum (1985) and Leffler (1978).

resilience comes into play. Holling (1986) used the term to refer to the ecosystem's ability to bounce back after disturbance (Rapport 1992b). Resilience has been used by ecologists as a synonym for elastic stability—the speed with which an ecosystem returns to its original condition following disturbance (Kimmins 1987). In Figure 4-1, resilience is the period of time that elapses between points (a) and (b).

Stability describes the frequency of disturbance in a system and its propensity to return to its former state. Total stability has been described as the area bounded by the curve below the normal operating range between points (a) and (b) in Figure 4-1 (Odum 1985). As the area under the curve decreases, due to either greater resistance or resilience, total stability increases. This is somewhat confusing rather than helpful, because stability has at least eight definitions in the ecological literature (Kimmins 1987). Two of them are resistance and resilience as described above. Unstable communities—that is, those which leave the "normal operating range" in Figure 4-1 due to frequent disturbance events—are often the most resilient because they are likely to contain many species which are adapted to a wide variety of environmental conditions (Holling 1973).

Odum (1985) said resistance and resilience may be mutually exclusive in a given ecosystem. For example, a California redwood forest with its thick bark and other adaptations is quite resistant to fire, but if it does burn, it will recover very slowly or perhaps never. In contrast, California chaparral vegetation is very easily burned, thus has little resistance, but recovers quickly and thus has excellent resilience. In general, ecosystems in benign physical environments can be characterized by more resistance and less resilience, and vice versa in uncertain physical environments (Odum 1985).

Moreover, depending on which variable is measured (e.g., leaf area index, species composition, water chemistry, etc.) one may come to different conclusions regarding resistance or resilience (J. Marshall, review comments).

Resilience is used frequently in current discussions of ecosystem health and management. It seems to have lost the scientific meaning of a measure of recovery time separate and distinct from resistance, which is less frequently mentioned in the same discussions. The concept of ecosystem resilience seems to have swallowed up ecosystem resistance, and has come to mean the ability of an ecosystem to recover from disturbance, rather than the time it takes to recover. It is confusing, but ecosystem resilience as it is now used includes the ability to resist change as well as recover quickly in the face of disturbance. However, Odum (1985) observed that these two properties may be mutually exclusive. We do not infer that the current usage of resilience is inappropriate, but wish to point out that it is often different than what appears in the scientific literature. In the following discussion, we will insert in brackets the term [resistance] to accompany resilience where it is appropriate.

Botkin (1993b) suggested different terminology—persistence and recurrence—to break from the traditional ecological concept of stability. This terminology, first presented by Botkin and Sobel (1975), has not yet caught hold. The apparent confusion regarding the concepts of resistance and resilience and the difficulty of measuring them both point to the need for a broader view of resilience than simply returning to a stable ecological state.

Resilience and stability have a large body of literature associated with them (see Pimm 1984, Holling 1986). Both concepts are related to general measures of health. Healthy organisms are resilient [and able to resist or withstand physical and biological forces that may be detrimental to them]. These concepts lead to a definition of health as the ability to [resist and] recover from stress. The greater this ability the healthier the system (Costanza 1992).

As an ecosystem develops through the process of succession, interactions between species become more complex. A change in the abundance of one species can result in major changes in other species. Repeated catastrophic disturbance, or long periods without disturbance, result in the homogenization, or sameness, of vegetation structure over a large area. This will in turn reduce many environmental refugia upon which some species may be dependent. In many areas the suppression of fires has predisposed the vegetation to these types of changes [and reduced their resistance to fire]. The maintenance of long-term productivity correlates strongly to ecosystem [resistance and] resilience. An important way to reduce loss of resilience is to manage for a diversity of successional stages across the landscape. This will help retain the functional relationships that lead to [resistance and] resilience in the first place. We are a long way from full understanding of the resilience of forest ecosystems (Gast et al. 1991). According to the Society of American Foresters Task Force report, ecosystems need resiliency to ensure continuing productivity when changes occur. Conserving biological diversity is identified as a key element in sustaining productivity over the long term (Norris et al. 1993).

The traditional focus of forest ecosystem resilience has been on the soil as the major factor affecting long-term forest productivity. Recently, the idea has been advanced that forest ecosystem resilience is also a function of diversity, in terms of species composition and vertical and horizontal structure. In some forests, the number of bird species and small mammals is closely related to the structural diversity of the forest, and it has been suggested that this will hold true for other animals. The actual relationship between animal diversity and plant diversity is more complicated than that. These ideas are part of what is generally called "new forestry" in the Pacific Northwest (Kimmins 1992).

The connection between ecosystem stability and resilience/resistance is less than clear in the ecological literature. A controversy over ecosystem diversity and stability [as represented by resistance] arose in the mid-1960s with the discovery that the least diverse communities are usually the most resilient ones, partly because they are made up of relatively few organisms that are tolerant of a wide range of environmental conditions (Denslow 1985). Kimmins (1987) said this relationship between resilience and diversity is extremely complex and generalization is difficult. Furthermore, "The ability of an ecosystem to recover from perturbation is probably more closely related to its ability to process energy than to its diversity" (Kimmins 1987).

Stability in existing social systems can be enhanced by establishing realistic natural resource output targets and meeting them (Quigley 1992). However, it may not be possible to force forest ecosystems into long-term stable states, given the unknowns of future resource demands, economics, climate change, and tree and pest coevolution (Wickman 1992).

Stability is not as useful a term as is resilience in discussions of ecosystems (Botkin 1990). The reason for this is that there are eight definitions of stability (Kimmins 1987). One of them is resilience, another is resistance. Costanza (1992), citing Holling (1986), said resilience should be thought of as "the ability of a system to maintain its structure and patterns of behavior in the face of disturbance." This is broader than the definition of resilience associated with Figure 4-1. Today, emphasis is placed on the adaptive nature of ecosystems, rather than how fast they can shrug off perturbations, and return to a former state. According to Costanza, healthy systems can absorb stress and "use it creatively" rather than simply resisting it and maintaining their former configurations. As an example, he said many coniferous forests have adapted to frequent low-intensity fires as part of their overall functioning [and are thus resistant to this form of disturbance]. Suppressing stress from wildfire can be counterproductive [that is, reduce resistance] and, according to Costanza (1992), "lead to larger, more destructive fires in the long run." We will explore this important subject in detail in Chapter 7.

Costanza (1992) reported that an interdisciplinary workshop adopted the following working definition of ecosystem health:

> An ecological system is healthy and free from "distress syndrome" if it is stable and sustainable—that is, if it is active and maintains its organization and autonomy over time and is resilient to stress. Ecosystem health is thus closely linked to the idea of sustainability, which is seen to be a comprehensive, multiscale, dynamic measure of system resilience, organization, and vigor. This definition is applicable to all complex systems from cells to ecosystems to economic systems (hence it is comprehensive and multiscale) and allows for the fact that systems may be growing and developing as a result of both natural and cultural influences.

Costanza (1992) observed that although individual organisms are not sustainable indefinitely, the populations and ecosystems of which they are a part may be. To be healthy and sustainable, a system must maintain its activity level, internal structure, organization of processes linked to one another, and must be resilient [and somewhat resistant] to outside stresses over a time and space frame relevant to that system (Costanza 1992).

Quantifying resilience depends on the ability to predict the dynamics of the system under stress, which requires sophisticated computer simulation models to synthesize knowledge about complex ecosystem functions. Beyond its use for developing health indices, modeling is essential for regional ecosystem management and predicting responses to a host of potential impacts (Costanza 1992).

Resilience has become part of the dialogue on forest conditions and sustainability. Studies of historic patterns of forest use and forest condition over the last century conclude that at the national level, forests today are in better condition than at any time in this century (Frederick and Sedjo 1991). One factor contributing to this has been the basic resilience of forest resources in recovering from disturbance and responding to management (MacCleery 1992). In its predictions that now date back many decades, the USDA Forest Service has consistently underestimated forest growth that has actually occurred (Clawson 1979). But this does not mean that each and every forest today is in the best condition it has been in over the past century.

"Sustainability". Because forest health is about sustainable ecosystems, it is necessary to define "sustainable." That task, however, is not as simple as going to the dictionary. Of the ten definitions of the verb "sustain," only one may apply to this situation: "endure without giving way or yielding" (Random House 1971).

Sustainability has become an important environmental policy consideration at local, state, regional, national, and international levels. Ideas about measuring sustainability range from narrowly defined economic productivity over time to ecologically-based criteria (Haskell et al. 1992). Indeed, Gale and Cordray (1991) identified eight different concepts of what forests could sustain. In the end, the choice of what a forest is to sustain must be socially acceptable.

Addressing the issue of resource sustainability, Frederick and Sedjo (1991) said resource systems are often out of balance in the short run. They use forest growth and mortality as a reference, as we will in Chapter 14 to assess Idaho forest conditions. In young forests, growth tends to exceed mortality. Old forests ultimately decline as a result of natural events, including insects, disease, or fire. They said growth and mortality are roughly in balance only in a mature forest. This balance is readily broken by natural events or human interference such as logging. Sustainability, however, is determined by the long-term relationship of growth and loss (Frederick and Sedjo 1991).

Sustainability is dynamic, not static. Ecosystems are created and partially maintained by disturbance regimes, making sustainability a concept of change that occurs within the dynamic ranges of disturbance frequency, extent, intensity, and severity. Maintaining the effects of disturbances within this range of variability is a useful conservation strategy for maintaining biodiversity and long-term site productivity that existed before European settlement (Everett et al. 1993). The idea of using the historic range of variability in ecosystem characteristics as a reference point (as opposed to a goal) for ecosystem management is discussed in more detail in Chapter 10.

For any given ecosystem, several sustainable states may exist and provide different landscape characteristics and flows of renewable resources. Current knowledge limits sustainable states to those within historical landscape patterns and disturbance regimes, even though other landscape patterns and species compositions may be sustainable. Sustainable ecosystems are the integration of social expectations with land potentials, technology, and economic factors (Everett et al. 1993).

Conclusions

Forest health discussions in the Inland West revolve around the concepts of resilience and sustainability. Implicit in these discussions is that forests are ecosystems, not just stands of trees. The ecosystem concept is a powerful communication device, as is the concept of health. Because ecosystems and health are broad and inclusive concepts, the scientific measurement of forest health is difficult. Insect and disease epidemics and catastrophic wildfires occur, and may be tied to unhealthy forest conditions. Until the measurements are taken and comparison standards developed, we can't say whether a forest is healthy or not, even if insects and diseases are epidemic and wildfires are catastrophic. Resilience, as it is used by ecologists, cannot be measured. Neither can sustainability. Ecosystem health measurement problems can be overcome.

Chapter 13 offers some suggestions for doing this. Until objective measurements are made and compared against standards that have yet to be established, discussions of forest health conditions will remain subjective.

Chapter 5. What is Forest Health?

Even though forest health has been described as a buzzword, it is a new piece of jargon used in forest ecosystem management discussions and policy deliberations. Because of that, it is important to provide some definition for the term. As Professor John Marshall (review comments) noted, scientists develop new jargon in part to break clear from the connotations of existing words. The development of forest health is an example of such an effort, similar, according to Marshall, to the quandary evolutionary biologists once found themselves in. They borrowed the terms "evolve" and "adapt" that had other meanings, and fitted them to their own purposes, with precise definitions that have since been applied with reasonable consistently. Economists also use terms like demand and supply with narrower definitions than others use those terms. Forest health is useful as a communication device, but if it is to become scientifically meaningful, it has to be defined before it can be measured.

In discussions of forest resource management and policy throughout the United States today, the health of forests is frequently mentioned as a component of what some people now refer to as sustainable ecosystems. Ecosystem health concepts are embodied in the term sustainability (Riitters et al. 1990, Costanza 1992). Indeed, in the Eastside Forest Ecosystem Health Assessment (Everett et al. 1993) a healthy forest is defined as a sustainable forest ecosystem. The terms health, ecosystem management, and sustainability defy precise definition—they tend to mean whatever people want them to mean.

Towards a Definition

Forest health appeared only lately in forestry literature; Waring (1980) and Smith (1985, 1990) were some of the first forest scientists to use the term. It generally refers to forest decline phenomena that became a subject of scientific inquiry in the 1980s.

Scientists with the U.S. Environmental Protection Agency (Riitters et al. 1990) said, "No widely accepted definition of forest health exists." Smith (1990) said definitions are critical in any assessment of forest health. Recent literature was reviewed for existing definitions (see Appendix A) and revealed a general lack of agreement on an acceptable definition. We therefore developed one, based on what was presented in preceding chapters and what follows.

The concept of forest health, however defined, is a useful communication device for relating forest conditions to something people understand, thus attracting their attention to forest ecosystem management problems and inspiring their imagination toward socially desirable solutions. Forest health focuses attention on a) the prevention of socially undesirable forest conditions by integrating the various concerns of protecting the forest from insects, disease, and wildfire in an ecological framework; and b) the restoration of socially desired forest conditions as needed.

Forest ecosystem health. The attempt to define forest health necessarily begins by defining the three words in the phrase *forest ecosystem health.* Verbatim definitions selected for their precision and brevity are presented below.

Forest. A forest is an ecosystem characterized by a more or less dense and extensive tree cover. More particularly, a plant community predominantly of trees and other woody vegetation, growing more or less closely together (Society of American Foresters 1983).

Ecosystem. Many definitions of an ecosystem exist. We selected these: 1) any complex of living organisms with their environment, that we isolate mentally for the purposes of study (Society of American Foresters 1983); 2) a set of interacting species and their local, nonbiological environment, functioning together to sustain life (Botkin 1990); and 3) the complex of biotic and abiotic elements interacting over time and space (Everett et al. 1993).

Health. The Random House dictionary (1971) provides four definitions of health. All but one applies to the general condition of the human body and mind. The fourth and broadest definition of health is: "vigor; vitality: *economic health.*"

Forest ecosystem health. Taken together, the three preceding definitions lead one to define forest health as the vigor or vitality of interacting biotic and abiotic elements of a system characterized by extensive tree cover that function together to sustain life and are isolated mentally for human purposes. This definition is inclusive, but rather cumbersome. We therefore developed the shorter definition presented in the abstract, in the introduction, and at the conclusion of this chapter.

Forest health is a complex subject. In its strategic plan for forest health, the USDA Forest Service (1988) stated,

> Forest health is a complex subject with both real and perceived problems which can arouse strong emotions. The actual problems are the product of events occurring over a long period of time. The perceived problems reflect an incomplete understanding of forest ecosystems, the biological processes operating within them, and alternative views of the purposes to be served by the forest.

In recognition of substantial areas of dead and dying trees on federal lands as a result of drought, insect infestations, disease, fire, windstorm, or other causes, bills were introduced in both Houses of Congress in early 1993. In the House of Representatives, Rep. Larry LaRocco (D-ID) introduced the "National Forest Health Act" (H.R. 229) in January 1993. Forest health was defined in H.R. 229 as:

> The condition of the forest in terms of its capacity to tolerate natural and human influences (such as insects, diseases, atmospheric deposition, silvicultural practices, harvesting practices, and wildfire) within the natural range of variability for the ecological system involved and the desired range of ecological variability for the land use in and around the forest unit.

When the concept of health is imposed on a forest, the complexity of the system must be considered. Otherwise, important ecosystem aspects may be overlooked. Aspects that must be considered include the spatial and temporal settings, which are reflected in the diversity of the forest. Some spatial aspects, such as distribution of old-growth forest vegetation, may apply to the entire forest but others, such as distribution of riparian areas, can be extremely limited. Likewise a forest changes over time. For example, a forest supports different vegetation in an early successional stage than it does later when it reaches a climax condition.

Characteristics of the forest ecosystem can be scientifically measured and compared to indicate some tangible aspects of forest health but forest health is a human perception; hence, the concept must also consider human values. This idea was expressed in the National Forest Health Monitoring Plan (USDA Forest Service 1992a): "Although forest condition can be specified and measured objectively, forest health carries an element of subjectivity, as it is a value judgement."

Because forest health is a human perception, it is difficult to define in a way acceptable to everyone. This is exemplified by the multitude of definitions in use (see Appendix A). The work of others to develop a definition of forest health is presented in the following sections.

Forest Health and the USDA Forest Service

The USDA Forest Service has been the leading proponent for forest health as both a research and a resource management consideration. The Society of American Foresters now seems to be comfortable with the term forest health, but has not taken a position on forest health management or research. Some forest scientists have begun to frame discussions of forest protection and forest management in a forest health context. Scientists from outside the forestry community discuss ecosystem health, and sometimes cite forestry examples in broader discussions.

President Clinton (1993, emphasis added) seems to be comfortable with the term forest health:

> Regardless of what we are doing, our efforts [to resolve the "logjam" or gridlock in the forests of

> the Pacific Northwest] must be guided, it seems to me, by five fundamental principles. First, we must never forget the human and the economic dimensions of these problems. Where sound management policies can *preserve the health of forest lands*, sales should go forward. Where this requirement cannot be met, we need to do our best to offer new economic opportunities for year-round, high-wage, high-skill jobs. Second, as we craft a plan, we need to *protect the long-term health of our forests, our wildlife and our waterways*.

The term forest health has been defined differently by various Forest Service scientists. Sometimes the concept is featured in discussions of ecosystem management, and sometimes it is totally ignored. The different and inconsistent approaches of various Forest Service units to definitions and applications of forest health are in total confusing, but nonetheless instructive. It is apparent that forest health is a relatively new and therefore evolving concept. It is perhaps evolved to the point where the Forest Service can define forest health so it can be used consistently across the nation.

The various definitions of forest health used by the Forest Service are presented here in an attempt to determine what the concept means. Definitions in the following sections range in scope from nationwide to regional to individual national forests.

Nationwide pest management strategy. In its strategic plan for managing forest health, the Forest Service (1988) came up with this definition:

> A desired state of forest health is a condition where biotic and abiotic influences on the forest (i.e., insects, diseases, atmospheric deposition, silvicultural treatments, harvesting practices) do not threaten management objectives for a given forest unit now or in the future.
>
> A healthy forest can be described by many standards, each related to a management objective for the forest. No single standard or definition covers all objectives. The diversity emphasizes the complexity of the problem. Each forest manager will have to decide, based on the management objectives for a particular piece of forest, what actions are needed to provide the forest condition and productivity desired.

The above definition maintains the traditional stance of the Forest Service, indeed the forestry profession, that the most important part of forest management, and always the most controversial, is deciding what the forest should provide. Because forests provide a variety of things, controversy and conflict are sure to follow, especially in federal forests that belong to everyone. Therefore a management-oriented definition of forest health adds little but the word "health" to the traditional management direction of providing multiple goods and services, and its associated problems.

The 1988 definition above and the attendant concerns behind it were not prominently featured in the long-term strategic plan for the nation's forest and rangeland resources that the Forest Service is mandated to provide every five years under the Forest and Rangeland Renewable Resources Planning Act of 1974, or RPA. The latest version of RPA was published in 1990 (USDA Forest Service 1990a) and had little to say about forest health. The RPA strategic plan mentioned forest health only in the context of possible climate change and air pollution, as the focus of a 10-year Forest Service research program called Forest Health, Productivity and Diversity in a Changing Atmospheric Environment. This program was a component of President Bush's comprehensive U.S. Global Change Research Program (USDA Forest Service 1990a).

The USDA Forest Service (1993c) has revised its strategic plan for providing "Healthy Forests for America's Future." The definition of forest health as tied to management objectives remains the same, but is now tempered with the ideas of Monnig and Byler (1992) that management objectives need to reflect ecosystem limitations. The definition in the revised 1993 plan now explicitly links forest health to the land management planning process for national forests required by the National Forest Management Act of 1976, but because it does not reflect ecosystem concerns, it is likely to continue to be opposed by environmentalists.

National Forest Health Monitoring Program. Forest health can be defined by different standards that relate to differing management objectives for particular forested areas. Forests are expected to be healthy when biotic and abiotic influences do not threaten the attainment of management objectives now or in the future (USDA Forest Service 1992a). This definition reiterates the nationwide strategic plan definition described in the preceding section.

Northeastern Area State and Private Forestry. In its report on forest health in the northeastern states, ranging from Minnesota to Missouri to Maine, the State and Private Forestry division of the USDA Forest Service (1993a) defined forest health as follows (emphasis added):

> Forest health can be defined as the ability of a forest to recover from natural and human-caused stressors.... Over time, single or multiple stressors may alter trees to a point where they can no longer recover and begin to "decline," exhibiting crown dieback and deterioration. This decline may be reflected by changes in rates of succession, forest composition and structure, or general productivity. Large outbreaks of insects and disease do not automatically indicate a deterioration in forest health.... It is desirable to establish and maintain forests that are as resilient as possible to natural and human-caused stressors, while meeting the values, needs, and expectations of society.

Ecosystem Management Coordination Team—Regions 1, 2, 3, & 4. Developed first at the Region 1 office in Missoula, Montana, the concept of "sustaining ecological systems" has as one of its stated goals, "caring for the land by sustaining healthy ecosystems" (see Appendix 1 in Caraher et al. 1992). The evolved concept of health is defined by Region 1 as follows: "An ecosystem is healthy if it maintains its complexity and capacity for self-organization (resiliency)."

This definition seems to be at odds with the definition in (Chapter 4) of resiliency as the ability to respond or the time it takes to recover from disturbance, further confusing what the Forest Service means by forest health.

In the context of ecosystem management as envisioned by the Forest Service, forest health has been identified as a concern by Deputy Chief Overbay, as cited by Quigley and MacDonald (1993), scientists in Region 6:

> Ecosystem management... rests on six principles. [The first is] sustainability. Restore and maintain diversity, health, and productivity of forest and grasslands. Provide commodities and uses consistent with sustained vitality and resiliency of ecological systems.

Blue Mountains National Forests—Region 6. The three national forests in Northeastern Oregon have been heavily hit by recent insect outbreaks (Gast et al. 1991). The Blue Mountains Natural Resources Institute, involving many participants, has been formed to develop solutions to the problem (see McLean 1992). The Blue Mountains Forest Health Report (Gast et al. 1991) defined forest health as:

> The condition of the forest based on diversity of natural features of the landscape, distribution of plant communities exhibiting various stages of succession, and the degree to which naturally occurring fauna occupy habitats that are varied and equitably distributed across the landscape.

This definition is ecosystem-oriented, without even a mention of management objectives, therefore is in contrast with the Forest Service national strategic plan definition. The Blue Mountains report, however, used a definition for "catastrophic loss" tied to objectives. This sounded very much like the forest health definition in the Forest Service national strategic plan for forest health, but appeared in a different context outside the definition of forest health.

A key feature of a forest health definition is to what extent ecosystem concerns are emphasized, and to what extent management objective-oriented concerns are emphasized. A socially acceptable definition of forest health will need to consider management objectives and ecosystem properties.

Eastside Forest Ecosystem Health Assessment—Region 6. This comprehensive assessment of forest ecosystems in eastern Washington and eastern Oregon was completed by the Forest Service at the request of Rep. Tom Foley (D-WA), Speaker of the House of Representatives, and Sen. Mark Hatfield (R-OR).

Other than being prominently featured in the title of the report, forest ecosystem "health" is not even mentioned, let alone defined, in the text of the 57-page Executive Summary report by Everett et al. (1993). The report does say that some eastside ecosystems are stressed and unstable, points out the reasons why, and presents a strategy for restoring affected ecosystems. According to team leader Richard Everett (review comments), the eastside assessment team did not attempt to define forest health because of ambiguities in existing Forest Service definitions. They instead recognized forest health as a symptom, and sustainable ecosystems as the broader issue that they were better equipped to address.

National Center of Forest Health Management. The creation of this USDA Forest Service institution in Morgantown, West Virginia, was announced midway through 1993. The center will serve as a national facility to develop new technologies and help move research findings into practice. It was announced as "the nation's only facility to focus attention on forest insect and disease problems that threaten the health of forests." It's first project will be to continue an existing research project on gypsy moth control (*Journal of Forestry* 1993b). One reviewer of this report felt some emphasis should be placed on the word only in the preceding quotation, and that this situation is unfortunate (G. Filip, review comments).

Boise National Forest. This national forest in southwestern Idaho has identified its top resource management challenge as restoring and improving the health of the forest, and has a three-part strategy for doing so (Boise National Forest 1992a). The forest has defined forest health as "a condition where biotic and abiotic influences on the forest do not threaten management objectives for a given forest unit now and in the future" (Boise National Forest 1992b), thus parroting the Forest Service (1988) strategic plan definition. This approach is controversial, because the first part of the strategy is the short-term action of quickly removing dead trees. Perhaps part of the problem perceived by critics of the strategy is the management-oriented approach, which is in contrast with the ecosystem approach as defined for the neighboring forests in the Blue Mountains. The Boise National Forest health strategy is presented and analyzed in Chapter 16.

Summary. A healthy forest has been defined by the USDA Forest Service in two fundamentally different ways. The first emphasizes maintaining management objectives and is embodied in the nationwide strategic plan for forest health (USDA Forest Service 1988, 1993c). The second emphasizes maintaining ecosystem structure and function and is embodied in the Blue Mountains forest health report (Gast et al. 1991). These two different approaches to forest health can be reconciled by taking a multi-disciplinary integrated view of forest health. This idea is further developed in the rest of this chapter.

Two Approaches to Forest Health

What do people want from forests? It is difficult to determine what mix of goods and services forests should provide. Because forests can provide many things, debates over what they should provide are at the core of all forest management policy debates (Cubbage et al. 1993). Everyone desires healthy forests. How can that be accomplished in light of conflicting human needs?

As a starting point, two approaches are available for considering whether or not a forest is healthy. Both are necessary considerations, and both lead to the development of important ideas that need to be captured in a complete definition of forest health. The first approach is to focus on forest management objectives, the second is to focus on forest ecosystem function. Judgments about forest health need to consider both ecosystem function and management objectives (Monnig and Byler 1992).

Objective-oriented approach. A management objective-oriented approach has led the USDA Forest Service (1988, 1993a) to this definition: "an unhealthy forest inhibits managers from achieving objectives; a healthy forest does not pose such obstacles." It follows that a healthy forest may not be insect-free or pathogen-free, but sufficiently free of pest damage to meet management objectives (Byler and Zimmer-Grove 1991). Furthermore, a forest can be maintained in such condition that it will meet the objectives of future generations, which may be different than those of today and require maintaining various options.

There are two challenges in this definition. First, management to achieve objectives requires a clear and explicit statement of those objectives so the managers know whether they are on target to meet the objectives. Much of the forest policy debate about public forest management stems from disagreement over management objectives. Second, objectives must reflect limitations posed by ecosystem characteristics or properties, and there is limited information to predict ecosystem changes.

Ecosystem-oriented approach. Ecosystems are comprised of various components. Some components might be in a healthy or sustainable condition while others may not be. Ecosystems are dynamic. It is therefore conceptually difficult to think of components being in some kind of equilibrium or balance. A more feasible approach is to protect desirable ecosystem properties. Resistance and resilience are properties that enable the system to persist in many different states or successional stages. Resilience is the ability of the ecosystem to respond to disturbances. The concept of resilience as it is commonly used incorporates the idea of resistance to disturbance as well as the period of time it takes a system to respond. Botkin (1993b) has suggested persistence as a better term to describe this ecosystem property, but it is perhaps too late to discard the widely-used notion of resilience. Whatever it is called, this ecosystem property needs to be protected to ensure ecosystem sustainability.

Selecting a preferred ecosystem state as a management objective for a particular forest is a subjective undertaking, and difficult (perhaps impossible) because change is a natural property of ecosystems. To produce a healthy forest, managers need to expand their vision.

Professionals involved with forest resources are driven by a variety of concerns implied by the terms health, ecosystem management, and sustainability to move from stand management to a broader view that manages across the landscape. These concerns include current issues such as deforestation, habitat loss, air and water pollution, global climate change, damage from a variety of forest insects and diseases, and management practices.

The change in resource management philosophy (some call it a revolution) is a shift from sustained yield—usually expressed in terms of outputs—to sustainability—often expressed in terms of a forest condition or outcomes. Management focus is shifting to a more inclusive view of what remains in the forest ecosystem after management activities, rather than primarily on what goods and services are produced by those activities. Forest health enters the discussion to the extent that ecosystem management is designed to leave a "healthy" forest. The dividing line between healthy and unhealthy, however, remains elusive.

The Role of Forest Management Objectives

The analogy between human health and forest health is useful despite its limitations. People whose recreational pursuits are relatively sedentary do not have to achieve the same state of health to enjoy their activity as do those who prefer more vigorous activity. A walker does not need to achieve the same state of health as a jogger, who does not need the same state of health as a marathon runner. To some extent, then, health condition is defined by what the person intends to do. A person might be healthy enough to enjoy a vigorous hike on a maintained forest trail; the same person may not be healthy enough to backpack in the mountains.

One might therefore expect different states of health for forests that have dominant objectives for timber production, or wildlife habitat, or back-country recreation. To some extent, then, forest health condition needs to be defined in the context of what a forest is to be used for, or what a forest is to sustain. Forest health therefore does not define what should be done with a forest, but helps define what functions and products a forest can provide. Only people can set management objectives for a forest.

According to the Eastside Forest Ecosystem Health Assessment (Everett et al. 1993), management goals or objectives play an important role in federal forest planning. Goals must be clearly articulated and expressed in terms of effort, risks, benefits, costs, and tradeoffs. Management practices cannot be expected to achieve contradictory goals. Management is therefore a search for the common ground, and conflicting or ambiguous goals need to be clarified in the planning process before effective management can begin (Everett et al. 1993). This is perhaps the most difficult challenge in managing public resources. It is forest ecosystems, not just forests, that need to be managed.

The idea of health fails when used to describe a whole ecosystem because it is not possible to objectively define what constitutes a healthy ecosystem, given that one organism's gain is often another organism's loss (Marshall 1993). Similarly, disturbance in a forest stand may be a stabilizing activity at the larger landscape scale by promoting a variety or diversity of landscapes (R. Everett, review comment).

Marshall (1993) pointed out that because the health of a forest ecosystem is determined by subjective values rather than any single objective measurement, the idea of tying ecosystem health to management objectives is not very useful. Using this approach, it would be possible to change the health condition of a forest ecosystem simply by changing the management objective. For example, the forested area that has been damaged by smelter activities near Kellogg, Idaho, could be defined as a healthy forest if the objective is to use it as a ski area (Marshall 1993).

The idea of health works better when applied to a forest rather than a forest ecosystem. Explicit and clear objectives for the use of a forested area are necessary guidelines for managers to follow. Without them, gridlock is inevitable, and no one gets what they want.

USDA Forest Service Pest Management (1993c) has slightly tempered its earlier (1988) definition of forest health as tied to management objectives by recognizing that the relative health of ecosystems will pose constraints on forest management. Given the complexity of forest ecosystems, this is probably as far as forest scientists can go with forest ecosystem health concepts. Forest resource managers will have to look somewhere other than forest ecosystem health for management guidelines or objectives. People interested in different uses and outputs from the forest will need to determine what individual forest areas are to be used for—whether they are called forested landscapes or watersheds or ecosystems. The concept of ecosystem health cannot be expected to help resolve these conflicts.

The major forestry question is, according to Kimmins (1987), how to make timber production compatible with other land uses, not whether timber production should be an objective of land management. Having said that, he concluded that the decision may frequently be reached not to harvest the timber. A primary focus of forestry, then, is determining the compatibility of timber production with wildlife, fish, water, recreation, and other resource values. Compatibility of diverse values and ecosystem components is a key feature of sustainability in complex ecosystems.

Integrated Workshop Definition of Ecosystem Health

In spite of the scientific difficulties of defining and then implementing concepts of ecosystem health, the idea has captured the imagination of policymakers and is part of the dialogue surrounding public natural resource management ideas. It is perhaps too late to hope the buzzword will buzz off. If only because of its power as a communication device, careful attempts to define the concept of ecosystem health are necessary today.

Ecosystem health needs to be defined in practical terms. Although the parallel between medicine and environmental protection does not always hold (Norton 1992), the unifying idea of resource management is nevertheless the idea of protecting and restoring ecological processes, with the goal of protecting the autonomous, self-integrative processes of nature as an essential element in a new ethic of sustainability (Haskell et al. 1992).

Haskell et al. (1992) observed that health can be easily defined negatively—that is, health is the absence of disease. Forests have endemic levels of disease and insects whose function is to provide disturbance effects that create a diversity of stand conditions across the landscape (R. Everett review comment).

Haskell et al. (1992) stated that the preferred approach to defining ecosystem health is an interdisciplinary definition that states more positively the characteristics of healthy systems. Defining ecosystem health involves the identification of important indicators of health (such as a species or a group of species), the identification of important endpoints of health (such as relative stability and "creativity"), and, finally, the identification of a healthy ecosystem state that incorporates human values (Haskell et al. 1992). Costanza (1992) illustrated that indicators and endpoints do not require much integration and are quantifiable with a fairly high degree of precision. Measures of a healthy ecosystem state are less precise but are much more comprehensive and relevant. Such measures require integration and modeling (Haskell et al. 1992).

Haskell et al. (1992) reported that workshop participants from various disciplines arrived at a working definition of ecosystem health that incorporated most of the above considerations. Health was defined in terms of four major characteristics applicable to any complex system: *sustainability*, which is a function of *activity, organization,* and *resilience*. Thus the workshop participants concluded with this definition (Haskell et al. 1992):

> An ecological system is healthy and free from "distress syndrome" if it is stable and sustainable—that is, if it is active and maintains its organization and autonomy over time and is resilient to stress.

Haskell et al. (1992) said this definition can be applied to all complex systems. It allows for the fact that ecosystems are growing and developing in response to both natural and cultural influences. *Sustainability* is a key concept in this definition, which implies that a system can maintain its structure and function over time. Following this definition, a diseased system is one that is not sustainable, that will eventually cease to exist. "Distress syndrome" refers to the irreversible process of system breakdown leading to collapse (Haskell et al. 1992). The problem with this definition is the perpetuation of the traditional idea that ecosystem stability is achievable. This simply is not the case in forest ecosystems (see Chapter 4).

Rapport (1992b), using the human health analogy, said a healthy ecosystem is whatever ecologists, environmentalists, and the public deem it to be. This is no less committal than the approach of medical practioners, who have by and large discarded objective standards in favor of considerations such as life goals of individual people. In the ecological realm, one generally confers the connotation of health to a state of nature (whether managed or pristine) that can be characterized by systems integrity; that is, a healthy nature exhibits certain fundamental properties of self-organizing complex systems. Ultimately, as in human medicine, determinations of the health status of ecosystems hinge on human values. What is desired or healthy must also take into account not only ecological values but also social and cultural values. These human values may differ markedly among various segments of society. The traditional medical model (detection of disease, identification of causes, finding a cure) is less applicable in the ecological context than an alternative model focusing on mechanisms for promoting healthiness rather than identifying symptoms or causes of disease. The difference is that the latter model focuses on system *capabilities* rather than system *disabilities*. Similarly, defining health as the absence of disease focuses on disabilities; defining health as the potential for ecosystems to recover after disturbance focuses on capabilities (Rapport 1992b).

According to Costanza (1992), the minimum characteristics of a practical definition of ecosystem health that apply to complex systems at all scales are: [1] an integrated measure of system resilience, balance, organization (including diversity), and vigor (metabolism); [2] based on a comprehensive description of the system, because looking at only one part of the system implicitly gives the remaining parts zero weight; [3] use weighting factors for different system components based on how functionally dependent system sustainability is on the various components; and [4] the definition should be hierarchial to account for the interdependence of various temporal and spatial scales (Costanza 1992).

The above definition is thorough, but certainly not simple. Whether or not it is practical, as Costanza (1992) claimed, remains to be demonstrated. Those who would define and measure ecosystem health need to consider all of these ecosystem characteristics, and place these ecological values in the context of human social and cultural values. It is a complex undertaking to operationalize the idea of ecosystem health.

Definition of Forest Health

Quigley (1992b) suggested that forest health be addressed in two parts. Part one could be an assessment of current status or condition relative to a baseline. Part two could describe the system's ability to meet social and cultural expectations now and in the future. Forest health assessment then is not a task that can be turned over to biological and physical scientists and technicians. As Quigley (1992b) put it, "Defining ecosystem health includes consideration of long-term ecosystem process and function as well as social values and institutions."

Our definition includes both these considerations. After considering the various attempts by many others to define forest health, we offer the simple definition provided at the beginning of the chapter:

> ***Forest health is a condition of forest ecosystems that sustains their complexity while providing for human needs.***

Beyond the Definition of Forest Health

Forest health is the condition of forest ecosystems. A declining condition, however measured, is the symptom of a health problem. Promoting healthy conditions will also promote sustainable forest ecosystems. Defining healthy conditions is a difficult undertaking. Avoidance of unhealthy conditions may be a more practical management approach.

Forest health emphasizes prevention of problems rather than merely treating them. Forest health problems often require management intervention to treat symptoms before prevention of future problems can be approached. For example, Byler and Zimmer-Grove (1991) said that insect and disease management in the prevention context involves recognizing stand conditions and site factors that put stands at risk, and modifying stand conditions through the appropriate use of silvicultural techniques, including prescribed fire. Management activities and policies as well as natural factors, determine forest conditions and are therefore important forest health topics. This is the subject of the next chapter.

Conclusions

Forest health is a condition of forest ecosystems that sustains their complexity while providing for human needs (O'Laughlin et al. 1994). This definition takes into account concerns for ecosystem sustainability as well as management objectives. It points out the need for socially determined ecosystem properties and forest uses that are to be sustained.

The idea of tying health to management objectives is not very useful because it would be possible to change health status simply by changing management objectives. In part, this is a result of the current lack of objective ways to measure ecosystem health. Approaches to determining objective measures are the subject of Chapter 13.

The challenge in creating an acceptable operational definition of forest health was to recognize that forests are ecosystems and the public desires not only sustained flows of goods and services from forests, but also sustainable forest ecosystems.

The USDA Forest Service has promoted the concept of forest health and now has a multitude of definitions. Some focus only to management objectives, and some focus only on ecosystem properties. A concise and consistent definition seems necessary if forest health is going to be an organizing theme for forestry research and management. Because forest health concerns are broad, the definition needs to be broad. We suggest that if the agency desires to use forest health in its discussions of forest ecosystem management, it had better start with a broader, simpler definition. At a minimum, a socially acceptable definition will have to say something about ecosystem properties and something about the objectives toward which management effort is focused.

A definition is only the beginning. Operationalizing the definition requires an understanding of forest conditions and how they are affected by management and policy decisions as well as natural factors. Then a way is needed to measure and monitor those conditions so management activity can be adapted to achieve socially desired conditions as outcomes or end points. As is true in other "health" contexts, it may be easier to identify when a forest if experiencing an "unhealthy" condition in one or more aspects than it is to define exactly what "healthy" means.

PART II. MANAGEMENT AND POLICY CONSIDERATIONS

Chapter 6. Factors Affecting Forest Health

Forest health is affected by many things. Disturbances may be caused by natural events or human activities that set ecosystems on new trajectories. Sometimes natural events are catastrophic and result in damage to trees and forests. Sometimes natural events change the composition and structure of forests stands more slowly. Human activities can also have either immediate or slower-acting effects on forests. If management policies are to promote healthy forests, a variety of factors need to be considered. In the Inland West, none of these factors are more important than fire exclusion.

Smith (1990) recognized four primary stress elements that affect the health of forests: limited water, limited nutrients, extremes in climate and topography, and the presence of fire in ecosystems. These elements affect forests by promoting or resisting disturbances of various kinds. All four of these elements are present in the Blue Mountains, making management of those ecosystems complex (Quigley 1992a). The latter two elements —extremes in climate and topography, and ecosystems where fire plays a role—are present throughout the state of Idaho. Water limitations are not as much a factor north of Idaho's Salmon River, where the lion's share (80%) of Idaho's forests are located. Mandzak and Moore (1994) said nutrition can affect forest health anywhere in the Inland West.

Kimmins (1987) said frequent but moderate ecosystem disturbance from fire, insects, wind, or disease tends to have little long-term effect on forest structure, growth rates, or other ecosystem properties. Infrequent disturbance, however, may be more severe and in some cases change forest structure and alter various ecosystem processes. Attempts to reduce the frequency of disturbance by fire protection or widespread use of insecticides may lead to situations where large areas of forests become more susceptible to catastrophic disturbances than would otherwise be the case. Preventing mortality of one kind could increase risk from another (Kimmins 1987).

The following sections review what is generally known about the various factors that affect Forest health.

Drought

Drought is a lack of precipitation for long enough to cause depletion of soil moisture and injury to trees and other vegetation (Hook et al. 1984). Drought stress may predispose plants to attack by insects and disease. For example, drought makes the foliage of grand fir (Parks 1993) and Douglas-fir more palatable to spruce budworm and tussock moth larvae (Kimmins 1987).

Substantial evidence has implicated drought as an initiator or contributor to declining forest health. Sustained drought halts photosynthesis, depletes carbohydrate reserves, and reduces canopy mass. Increased pathogen and insect activity in forests is also linked to drought stress (Smith 1990).

Insects and Diseases

Wickman (1992) observed that natural effects of drought and old age in combination with management actions following timber harvest and fire exclusion have resulted in the conversion of forests from pine to fir. These shade-tolerant fir stands are affected by several types of defoliating insects, bark beetles, root diseases, and mistletoe (Wickman 1992; see also Hadfield 1984, Wargo and Shaw 1985, Filip and Schmitt 1990, Byler et al. 1990, Byler and Zimmer-Grove 1991, Monnig and Byler 1992, Byler et al. in press).

Fire frequency in the Rocky Mountain region has been altered in the last 75 years, and outbreaks of defoliating insects have become increasingly prevalent. Damage from root rots and mistletoe pathogens have also increased in recent decades (Kimmins 1987). The increasing mortality, top kill, and growth loss caused by various pests have resulted in serious declines in productivity in the Blue Mountain forests (Wickman 1992) and elsewhere.

Harvey (1993) pointed out that localized centers of insect and disease activity have a natural role to play in creating diversity in forest structure and species composition. They are beneficial in long-lived tree communities such as ponderosa pine that occupy sites where water and nutrients are limited. Pests were important factors in the development and function of these ecosystems. Insects and disease should be recognized as parts of ecosystem dynamics. They can serve as valuable indicators of vegetation vigor and soil conditions. They also present potential disturbance situations for managers to consider (Harvey 1993, see also Haack and Byler 1993).

Nutrition

Nutrient deficiencies can predispose trees to insects and disease by stressing them much as drought does (Kimmins 1987). Professor James Moore (1993) of the University of Idaho described several linkages between potassium levels and insect and disease pests from studies conducted by the Intermountain Forest Tree Nutrition Cooperative. All Inland West forests sampled by the Nutrition Cooperative were deficient in nitrogen (N). Many were also deficient in potassium (K). K/N ratios are probably more important than absolute amounts of nutrients. Mandzak and Moore (1994) said the current state of knowledge suggests that inadequate tree nutrition, particularly a potassium shortage, influences tree chemistry such that inadequate plant defensive compounds are produced. Pathogens and insects are unusually successful in attacking such trees.

Changes in tree species composition can affect forest nutrition. Fir trees not only have more foliage than the pines they replaced, but also are greater users and storers of nutrients than pines per unit of leaf area. Moore (pers. comm.) sometimes refers to firs as "nutrient hogs."

Air Pollution

While not a factor in the Inland West, air pollution, climate change and ozone depletion, and climate change have significant effects on forests (Smith 1990, Clarkson and Schmandt 1992).

Animal Damage

Animals can damage or kill seedlings, saplings, and mature trees. Walstad and Norris (1992) observed that direct and indirect methods for controlling animal damage are effective, but are not entirely satisfactory to either forest resource managers or the public. A more holistic management approach of integrating such practices within the overall context of silviculture and forest protection could provide forests that are less susceptible to animal damage. An integrated approach would involve defining resource management objectives and constraints, characterizing potential animal damage problems, developing potential solutions, evaluating and selecting alternatives, implementing them, and evaluating and documenting program effectiveness. These six steps, when integrated in the forest management system, will foster healthy and productive forest ecosystems with minimal need for intervening methods of animal damage control (Walstad and Norris 1992).

Timber Management

Some forests in the inland West have been high-graded in the past. This practice of selectively removing only the most valuable trees has resulted in changes in tree species composition. Fire exclusion has resulted in dense stands, which is likely related to decreased tree vigor (Mutch 1993b). The following sub-sections address these topics.

Species composition. Gast et al. (1991) said a major factor contributing to deterioration of forest health in the Blue Mountains has been the conversion of pine stands to fir stands. At first this did not raise alarms because fir promised faster growth rates and shorter rotations than pine. Now there is a question whether fir stands will survive long enough to provide the benefits expected of forests on those sites once dominated by pines (Gast et al. 1991).

Past timber harvesting practices have contributed to current forest conditions primarily by changing species composition. Preferred timber species such as ponderosa pine were harvested without adequate consideration for pine regeneration. Weatherby (1993) said vegetative changes influenced by timber harvesting are not as easy to interpret as the changes caused by fire suppression, which accelerates succession toward a climax stage. For example, on a planning district in the Boise National Forest, in the 1950s selective harvesting and attempts in the mid-1970s and early 1980s to maintain and manage grand fir with uneven-aged practices tended to accelerate succession to climax. But even-aged timber management practices in use between the mid-1960s and early 1970s and between mid-1980s and early 1990s resulted in the removal of climax vegetation in some areas, with regeneration to earlier successional species. These "flip-flops" in management direction probably led to some areas becoming more susceptible to infestations of defoliating insects while other areas became less susceptible. Management practices have tremendous influences on the forest (Weatherby 1993).

Stand density. The density of trees in a stand may be linked to many forest health situations. Researchers mention stand density as a likely causal factor affecting forest health, but definitive research studies have not been done. At the landscape level, some dense stands may be desirable as habitat for certain wildlife at certain stages. Everett (review comment) suggested that northern spotted owls may need dense stands to protect them during molting. But in general, it would seem that dense stands promote conditions that are unhealthy.

Mutch (1993b) said studies in ponderosa pine forests have shown that increases in tree density on a site result in more rapid canopy closure, vertical fuel continuity (or the development of "ladder" fuels), and surface fuel loadings that result in extreme fire hazards over large areas. Fire exclusion and increased tree density likely lead to decreased tree vigor (and thus increased mortality from drought and disease), decreased production of shrub and herbaceous vegetation, decreased aesthetic values, decreased water availability and runoff, decreased nutrient availability, and altered wildlife habitat (Mutch 1993b).

Carlson (1993) said dense stands are often stressed for moisture and nutrients and may have a foliage chemistry or "food quality" preferred by western spruce budworm populations. Overcrowded, stressed stands of shade tolerant species are also at high risks from root disease, Douglas-fir tussock moth, and Douglas-fir dwarf mistletoe. Forest health can be enhanced by maintaining stand spacing to reduce moisture and nutrient stress, and by restoring species better suited to sites (Carlson 1993).

Eklund (1993) observed that in the vicinity of Boise, high stand density has had an influence on tree growth and form. Dense stands have developed small crowns, are poor in vigor, slow growing, and vulnerable to weather-related damage because of structural weakness. Density management is necessary for future stand health (Eklund 1993).

Fire Exclusion

In 1906 the USDA Forest Service became the protectors of the national forests, and started a policy of fire suppression whenever and wherever possible. This helped set the stage for today's forest conditions (Wickman 1992). Conditioning by years of educational efforts in support of wildfire suppression has led to widespread failure by the public to recognize that fire is a natural ecological factor in determining the structure and function of many of the world's ecosystems (Kimmins 1987). Current ecosystems throughout the Inland Northwest are unnatural because fire has been excluded from playing a role in ecosystem processes. Past management practices, including fire suppression, have resulted in forest ecosystems throughout the region that did not exist before forest manipulation by European settlers (Quigley 1992a).

Nowhere is this effort more noticeable than in the Blue Mountains of northeastern Oregon. The Blues were named for the smoke and haze from wildfires that continually shrouded the region during the dry season (Mutch et al. 1993). Parts of the Boise and Payette National Forests lie within the Blue Mountains ecoregion, and are today experiencing the same effects of past management practices, especially fire suppression.

The exclusion of fire through decades of wildfire suppression is perhaps the important consideration for understanding the current forest health situation, and for developing management strategies to deal with the many situations caused by fire exclusion. To develop that understanding, Chapter 7 focuses on fire ecology in forests of the inland West, with special attention on Idaho forests. Management considerations related to the effects of fire exclusion are addressed in Chapters 8, 15, 16, and 17.

Conclusions

Fire exclusion is one forest health factor that seems to be linked to all others. Forest conditions in Idaho are a result of the combined effects of past management practices, principally fire exclusion and timber harvesting. These practices have resulted in species conversion and predisposed forests to disturbances by insects and diseases. Limited moisture and nutrients also are important and are linked to species conversion, and thus to fire exclusion. Managers will need to consider the combined effects of these factors as they try to promote sustainable forest conditions.

Some research attention has focused and continues to focus on how these factors affect forests and what can be done about the situation. Wickman (1992) asked, "Why can't we make forests more vigorous and resistant to insect and disease outbreaks?" Livingston (review comments) said we can make forests more vigorous and resistant, and we try to, but with limited success. Part of the problem is that there is too much area to cover. Another problem lies with the objectives and goals of some forest owners and forest resource management agencies, who do not place a high priority on maintaining stand conditions that promote vigor and resistance. Wickman (1992) stated that the main reason we can't make forests more vigorous is that knowledge from studies of insects and diseases has not been integrated with knowledge from studies by plant ecologists, wildlife biologists, economists, and silviculturists. Filip (review comments) said work has been done under integrated pest management programs, and some has been transferred to resource managers. Perhaps the problem is more one of implementation than integration (G. Filip, review comments). Wickman hinted at the implementation problem, and said that a long-term approach to forest pest management is needed. He said it is time to stop trying just to treat the symptoms and instead make forests more resistant to insect and disease outbreaks through vegetation management projects on a landscape level (Wickman 1992).

Chapter 7. Fire Ecology in Idaho Forests

Fire played a key role in the processes establishing and maintaining forest ecosystems in Idaho. This chapter reviews what scientists know about the role of fire in forest ecosystems in the northern Rocky Mountains.

Vogl (1980) said fire or other disturbance is often a normal part of ecosystem function, and may be necessary for maintaining ecosystems when viewed from a long-term, large-scale perspective. Locally and in the near term, fire can significantly alter ecosystem structure and function, including canopy architecture, species composition, and productivity. The persistence of the ecosystem at the large-scale perspective may depend on the recurrence of these disturbances (Vogl 1980, cited in King 1993).

Christensen (1988) highlighted the role of fire in successional change, and pointed out that where fire is a natural disturbance factor, it is no longer possible to manage ecosystems by natural regulation:

> Successional change, by whatever mechanisms or pathways, does not necessarily lead to increasingly stable, self-reproducing climax communities....It often increases the likelihood of disturbances, which in turn alter the successional process. In the best of all possible worlds, we would simply "let it be" and allow natural processes to regulate ecosystem structure and function....This approach will not be possible when fire regimes must be maintained.

Christensen's message is clear. Successional processes do not always lead to stable climax communities, and when fire is a natural part of forest ecosystems, it is no longer possible to maintain these ecosystems by leaving them alone.

Role of Fire in Idaho Ecosystems

Scientific understanding of fire and other disturbances or perturbations in the development of vegetation has increased greatly. Some early ecologists ignored or underestimated the role of disturbance in the development of biotic communities. This perspective may have been the result either of attention given to primary successional processes or lack of appreciation of the importance of secondary succession.

The process of forest development after an overstory removal fire is referred to as secondary succession. The vegetation can be classified into a number of different stages as the forest redevelops. The stages prior to the climax stage are called seral stages or communities (Figure 7-1). A climax community is the culminating stage of plant succession. In the absence of natural or human-caused disturbances, the climax stage is capable of reproducing itself and persisting. The entire sequence of communities that lead to the development of climax stage is called a sere (Daubenmire 1968, Ricklefs 1990, Gast et al. 1991).

In 1920, Aldo Leopold wrote an article very critical of the concept of using fire as a tool in land management. He said, "Light-burning [prescribed fire] reduces the vitality and productiveness of the forage [and] destroys the humus in the soil necessary for rapid tree growth" and "now is the time to put the quietus on the agitation for light-burning." Leopold reflected the general sentiments regarding fire and natural resource management 70 years ago. However, after he spent four years in the southwestern forests, Leopold reversed this earlier position and became one of the first ecologists to recognize the importance of fire in many of the biotic communities of the Southwest (Leopold 1924).

Ecologist Frederick Clements (1935) wrote, "Under primitive conditions, the great climaxes of the globe must have remained essentially intact, since fires from natural causes must have been both infrequent and localized." It took two more decades before ecologists began to discuss the possibility of fire having a major influence on vegetation structure (Humphrey 1953, Daubenmire 1968). Clements' ideas may still reflect a general societal view of fire's relationship to vegetation today. People often assume that the "pristine" vegetation with its abundant wildlife populations viewed by early Euro-Americans in western North America was also a "climax" vegetation stage.

Seral Stages	Successional Stage
Skeletal forest	Early
↓	
Herbaceous	↓
↓	
Shrub/herb	Mid
↓	↓
Young pine/shrub	Late
↓	↓
Mature pine	Climax

Figure 7-1. Hypothetical secondary successional sequence (sere) following fire in climax ponderosa pine. Note: Due to specific site characteristics any given successional stage may not occur in some areas.

Contrary to what early ecologists knew, we now have numerous studies indicating that fire was common in many vegetation types. Fire has been the principal and most extensive initiator of forest succession in the northern Rocky Mountains for at least the last several thousand years. The severity of burning in these forests varies from light ground fires to severe crown fires (Stickney 1990). Fire suppression may disturb ecosystems in northern Rocky Mountain forest ecosystems more than natural, frequent fires (Vance and Wilson 1990). This conclusion was drawn after careful analysis of the Yellowstone fire of 1988 (Wakimoto 1990).

The Blue Mountains Forest Health Report (Gast et al. 1991) identified two consequences of fire suppression: [1] exclusion of periodic fire has contributed to changes in vegetation patterns, especially in areas where overstocked thickets of suppressed, stressed true firs have been allowed to replace stands of ponderosa pine, and [2] fuel loading and susceptibility to conflagration-sized wildfires have increased as a result of fire exclusion and management practices that foster disease and insect infestation.

Much of Idaho's pristine vegetation character has been shaped by varying amounts of fire. Examples include grasslands (Gruell et al. 1986), sagebrush steppe (Houston 1973; Gruell 1980, 1983, 1986; Arno and Gruell 1983), juniper woodlands (Burkhardt and Tisdale 1976), aspen woodlands (Loope and Gruell 1973, DeByle et al. 1987), and the forests of ponderosa pine (Weaver 1951, 1961; Arno 1980), Douglas-fir (Habeck and Mutch 1973, Arno 1980, Davis 1980, Davis et al. 1980), lodgepole pine (Brown 1975, Arno 1980, Tande 1980, Romme and Knight 1982), white pine (Marshall 1928), whitebark pine (Arno 1983, 1986; Morgan and Bunting 1990), cedar/hemlock (Arno and Davis 1980), and subalpine fir (Dunwiddie 1977; Romme 1980, 1982; Butler 1986). Even vegetation types of climates receiving higher precipitation, such as the Pacific coastal forests, are often greatly influenced by fire (Agee 1991, Hemstrom and Franklin 1982, Franklin 1988). Climax forests may have been relatively rare in many of the pristine Idaho forests (Leiberg 1897, 1899a, 1899b; Habeck and Mutch 1973). Habeck (1976) indicated that 35% of the Selway River drainage burned between 1860-1900. The magnitude of fire on the Idaho landscape may have been greater during the 1860-1935 period because of an unusually high occurrence of lightning fires and promiscuous burning of forests by Euro-American settlers (Wellner 1970).

Lightning caused fire ignitions in many areas (Taylor 1974). The literature is replete with examples of lightning-caused fires occurring in most of the vegetation types of North America. It is not uncommon for a dry lightning storm to cross the northern Great Basin and Snake River Plain, igniting 100 or more fires in its path. Northern Idaho has also had a history of lightning-caused fires (Flint 1930).

While lightning-caused fires were common in many vegetation types, one must not underestimate the influence of Native American Indians upon fire regimes (Arno 1980, Barrett 1980, Barrett and Arno 1982, Gruell 1985). Fire was used as a vegetation management tool for a number of purposes, including forage improvement for horses (after horses were introduced in the 16th century), fire hazard reduction near camps, and enhancement of grass seed, berry and camas production. In addition, fire was used extensively for communications, hunting, warfare, and ceremonial purposes. Barrett (1980) found that Douglas-fir sites in western Montana with historically higher concentrations of Indian usage had more frequent fires than similar vegetation with less human use.

Factors Determining Fire Occurrence

The historic occurrence of fire in a forest stand or plant community during the period before Euro-American settlement is often referred to as the fire-free-interval (FFI). Scientists also use the terms mean-fire-free-interval, fire-return-interval, or fire frequency. All these terms are generally synonymous. Some scientists may apply the terms slightly differently, which can affect the interpretation. The most common usage of these terms is to identify the average interval between fires at a given location, and is the context in which the term is used here. Some scientists, however, use these terms to note the presence of fire across a larger area, such as a small watershed of several hundred acres. Most fires do not burn an entire watershed, and some portions may not have burned at all during the period studied. FFI values given for studies using this definition tend to be slightly higher than those of the more common usage.

The inclusion of variation around the mean of the FFI is an important factor in the ecological effects of fire. For example, if a plant community had an FFI of 25 years, one must not assume that in fact the community burned every 25 years. For many ecosystems this variation in fire frequency was essential. For example, many ponderosa pine stands had an FFI of less than 15 years. If a fire occurred every 15 years, however, the trees within the stand would gradually disappear because recruitment would not replace attrition. Most trees could not attain sufficient size in 15 years to survive even a low intensity fire. Variation allowed portions of the community to escape fire for perhaps 30 years, during which time the young trees could become large enough to withstand a fire. Longer-than-average intervals also mean, of course, that at times there were also shorter-than-average intervals. These were also probably important for the survival of some species.

Fire occurrence depended on factors such as climate, fine fuel accumulation, topography, ignition sources, and vertical and horizontal continuity of fuels. Short FFI's in forest and woodland vegetation types usually resulted in low intensity surface fires. Longer intervals between fires were more likely to result in high intensity crown fires resulting in stand replacement. Fires in grassland and shrub steppe vegetation types resulted in the mortality of the aerial portions of trees and shrubs except under low intensity conditions.

The "natural" or "pristine" (pre-Euro-American settlement) fire occurrence is probably best estimated by the FFI. However, some cautions must be made. FFI's would include Indian burning activity and this activity may vary widely between locations. In addition, some Euro-American induced influences may have been initiated in some places prior to the settlement period. These include introduction of the horse, changes in Indian hunting methods following introduction of firearms, reduction of Indian populations due to disease, and changes in the geographic distribution of many Indian tribes.

Fire's Role in Climax Versus Seral Vegetation

Fire may function quite differently in seral communities as opposed to climax communities. (See Figure 7-1 and accompanying text or the **Glossary** to review these terms.) For example, the ponderosa pine forest type may be either seral or climax, depending upon site characteristics. In seral stands, fires were less frequent and burned more intensely than on climax ponderosa pine sites (Arno 1976).

Because of the historical importance of ponderosa pine and western white pine in Idaho, we will use these two forest types as examples in this section, and expand on them in Chapter 15.

Ponderosa pine. Due to its thick bark, long needles, and self-pruning capabilities, ponderosa pine is one of the most fire resistant trees in Idaho. Many forest vegetation habitat types in northern Idaho are dominated by ponderosa pine at all successional stages, including the climax (Daubenmire and Daubenmire 1968, Cooper et al. 1987). In climax ponderosa pine communities, fire primarily acts as a thinning agent, reducing the amount of regeneration that can successfully occur. If frequent enough, fire may prevent the forest from developing and maintaining a grassland community. This grassland community has been referred to as a "fire" or "pyric climax" in some ecology texts (Daubenmire 1968, Ricklefs 1990). If fire is removed from the system, then the pine-dominated forest can develop. Soil development will occur with the development of the forest stand. This process of simultaneous vegetation and soil development is referred to as "primary succession."

Ponderosa pine may also occur as an early succession stage in a wide variety of habitat types that are dominated by Douglas-fir or grand fir at near climax (Daubenmire and Daubenmire 1968, Cooper et al. 1987). Periodic fire will remove much of the conifer regeneration. If frequent enough, fire can maintain a quasi steady-state. If not frequent enough, the other more shade tolerant trees such as grand fir will slowly gain dominance or codominance in the stand. A high intensity overstory removal fire may kill both the ponderosa pine and the grand fir trees.

Western white pine. Western white pine is moderately fire resistant, and its relationship to fire is very different from ponderosa pine. Western white pine stands owe their very existence to fire (Flint 1930, Davis et al. 1980). White pine characteristically occurred in pure even-aged stands that developed following overstory removal fires that recycled stands and maintained seral vegetation types. It also frequently grows in association with other fire-resistant species such as lodgepole pine and western larch. Large expanses of white pine existed in northern Idaho and western Montana in the late 19th century as a result of immense fires that occurred in the 15th and 17th centuries. Less is known about the relationship of underburns in white pine. Logging, wildfire, and white pine blister rust had claimed most of the great northern Idaho stands prior to scientific interest in fire history research. Robert Marshall (1928) did date some fire scars in four stands of white pine on the Kaniksu National Forest in northern Idaho and western Montana. The forest had been burned in overstory removal fires in 1610 and 1687, and the white pine dated from the second fire. All four stands showed some evidence of underburning during the history of the stand. However, no particular trends were evident. Marshall summarized by saying, "And now for the conclusion—but there isn't any." This may be a classic statement in fire history studies. What Marshall probably meant was that fire played out its role in every stand in a slightly different manner, and this complexity could not be summarized in a single statement. This lesson should be remembered when considering the role of fire in other vegetation types as well as western white pine.

Fire Regimes

The term "fire regime" has been defined by

Heinselman (1978, 1981) as having the following elements: [1] fire type and intensity, [2] size, and [3] frequency. Kilgore (1981) added other characteristics such as fire severity, season, and pattern. Consequently, fire regimes varied greatly between vegetation types and geographic locations within a vegetation type. When fire occurs at short intervals of less than 20 years, the primary and secondary fire effects on vegetation composition are minor. The herbaceous component of the community becomes dominated by fire tolerant species. The fire will eliminate any tree seedlings or non-sprouting shrubs that are burned. Established sprouting shrubs may be top-killed or may be completely killed when burned at a young age because they may not have had an opportunity to develop sprouting potential. In forests, frequent fires tend to be benign or relatively harmless surface fires. The overstory may be affected in specific locations where fire intensity becomes high and causes mortality, but most of the stand remains intact. The Intermountain region probably does not have many vegetation types that burned under a short-interval FFI. Some big sagebrush communities in mountainous terrain may have been under this type of fire regime. The FFI's in ponderosa pine forests varied widely across its broad geographic and altitudinal range but studies in many areas indicate that it was less than 10 years in western Montana (Arno 1976), Arizona and New Mexico (Weaver 1951), southern Washington (Weaver 1961), central California (Kilgore and Taylor 1979), and eastern Oregon (Hall 1976). This may have been the case particularly in locations where Indians camped and used fire to keep the area free of shrub cover.

Many vegetation types in Idaho have intermediate FFI's of 20 to 75 years. Many seral ponderosa pine forests in western Montana and Idaho probably had intermediate-length intervals between fires (Arno 1976). The longer intervals between fires will permit more fire-sensitive species such as Douglas-fir and bitterbrush to establish on the site. The big sagebrush steppe may also have had natural fire intervals between 20 and 75 years (Houston 1973, Wright and Bailey 1982, Bunting et al. 1987). Intermediate length FFI's allow the fire-sensitive big sagebrush to dominate the site, and conifers such as Douglas-fir, ponderosa pine, or western juniper may also become established. Fires in these communities will then result in greater amounts of change in plant composition immediately after a fire.

When FFI's become extremely long (greater than 100 years) the natural role of fire within the community is often very different from the role it has in communities with short or intermediate FFI lengths. Short and intermediate length FFI's tend to be associated with fire regimes that maintain many of the seral species. A long FFI is usually associated with a fire regime characterized by high intensity, overstory replacement fires (Kilgore 1981, Agee 1991). The initial post-fire vegetation may be very different in species composition. Because of the high mortality of the pre-fire community, the site may be initially dominated by annual, biennial, and short-lived perennials that can become quickly established on the site. Examples of communities with the longer interval include many conifer forests and woodlands such as subalpine fir, cedar/hemlock, and climax pinyon-juniper. Being infrequent, however, does not necessarily make the role of fire less important in the functioning of a community. The dependence of many forested vegetation types on fire is well known, and includes lodgepole pine (Brown 1975), whitebark pine (Morgan and Bunting 1990) and coastal Douglas-fir (Agee 1991).

Before Euro-American Settlement. The impression about the nature of pre-settlement fire regimes of Idaho forests, particularly those of northern Idaho, that appears in the literature varies with the source. Some authors stressed high intensity, stand replacement type fires (Leiberg 1897, 1899a, 1899b; Romme 1980, 1982; Romme and Knight 1981, 1982; Wellner 1970). Others wrote more extensively about understory fires (Arno 1976, 1980; Burkhardt and Tisdale 1976; Davis 1980; Gruell 1985; Weaver 1951). Habeck and

Mutch (1973) combined the two approaches together. This difference was probably due to two factors: the type of fire evidence observed, and the type of forest studied. Leiberg, Romme, and Wellner used stand structure and the presence of snags as evidence of previous fires. These would be primarily a result of the last stand replacement fire. The other scientists used fire scars. This would have focused attention to the less intense fires that would leave at least a portion of the stand intact. Leiberg, Romme, and Wellner wrote primarily about the high precipitation forest types such as grand fir, white pine, and cedar/hemlock. The fire regimes in these forests tended to be dominated by the less frequent, more intense fires. Vegetations at the lower forest boundary and the drier forests (ponderosa pine, Douglas-fir, juniper) tended to have more frequent fires. This resulted in more underburns. Periodically, however, stand replacement fires also occurred within these types. Two notable exceptions to the generalization that frequent fires were usually underburns are mountain sagebrush steppe and aspen woodlands. Fires within these vegetation types, although frequent, were usually stand replacement fires. All sources of information, however, indicate that fire was a very common widespread factor that helped shape the composition of Idaho's pristine forests and woodlands (Table 7-1). Wellner (1970) indicated that it was the second most important factor in forest development, precipitation being the most important.

Effects of Euro-American Settlement. The general effect of Euro-American land management has been to increase the FFI as compared to the pre-settlement period. Fewer fires resulted from a number of activities including: [1] reduction of Indian-caused fires, [2] active fire suppression, [3] domestic livestock grazing, and [4] development of fuel discontinuities with roads, timber harvest, agricultural fields, etc. The importance of each activity varies locally. Livestock grazing has been a major factor in limiting fire on the grasslands, sagebrush steppe, juniper woodlands, and dry forested types. It is particularly important in arid and semiarid areas where a reduction of fine fuels by grazing in arid and semiarid vegetation severely limits fire potential. During most years in these vegetation types, fine fuel production is near or below the limit necessary to sustain fire spread. Grazing has also been a factor in remote rangeland areas where fire suppression is less effective due to increased response time. Fire suppression has been most effective in the mid and low elevation forests, and in high human population density areas. Fire in the higher elevation forests has probably been reduced by effects on the forest below, because major fire events often started in the lower forests and then spread into the upper elevations.

The increase in FFI's has had a great impact on the composition of vegetation throughout North America. Vegetation types with short pristine FFI's have generally been changed more than those with longer FFI's. That is, the absence of fire for 75 years in a vegetation type with a pristine fire occurrence of 10 years has a greater impact on vegetation composition than with an FFI of 50 years. Vegetation types with an extremely long FFI could potentially be changed, but are probably still within the expected range of variation in FFI.

The human-caused increase in FFI's has resulted in three types of changes in biotic communities. [1] Dry forest types (juniper and aspen woodlands, ponderosa pine and Douglas-fir forests) have advanced into traditionally non-forested vegetation areas such as grasslands, dry meadows and sagebrush steppe (Loope and Gruell 1973, Burkhardt and Tisdale 1976, Davis et al. 1980, Gruell 1980, 1983, Arno and Gruell 1983, Gruell et al. 1986). [2] Density of trees has increased in some woodland and forest types in which periodic fire acted as a natural thinning agent, including western juniper woodlands (Burkhardt and Tisdale 1976), ponderosa pine forests (Weaver 1961, Hall 1976, Arno 1980, Davis et al. 1980), and Douglas-fir forests (Davis et al. 1980). [3] Succession has converted some forest or woodland community types to another cover type. The process has often resulted in significant soil developmental

Table 7-1. Fire-Free-Intervals (FFI) of selected vegetation types of Idaho and adjacent locales during the period prior to active fire suppression[1] by the USDA Forest Service and other agencies.

Vegetation	**FFI (years)[2]**	**Location**	**Source**
Mountain big sagebrush steppe	20-25 20-30	northern Yellowstone southwestern Idaho	Houston (1973) Burkhardt & Tisdale (1976)
Western juniper	20-30	southwestern Idaho	Burkhardt & Tisdale (1976)
Ponderosa pine	2-18 <10 5-25	western Montana eastern Oregon various locations	Arno (1976) Hall (1976) Davis et al. (1980)
Douglas-fir	5-67 <10	western Montana western Montana	Arno (1976) Davis et al. (1980)
Lodgepole pine	2-68 75-250 27	western Montana northern Rocky Mtn. western Alberta	Arno (1976) Brown (1975) Tande (1979, 1980)
Western white pine	Species is seral to other conifers and established naturally following large intense fires. Underburns occurred in western white pine forests (Marshall 1928) but data are inadequate to make FFI estimate.		
Cedar/hemlock	50-150	northern Idaho	Arno & Davis (1980)
Subalpine fir	24-140 >200	western Montana western Montana	Davis et al. (1980) Davis et al. (1980)
Whitebark pine	33 13-46	western Montana western Wyoming	Arno (1976) Morgan & Bunting (1990)

[1] Effective suppression is generally thought to have started about 1900 and gradually intensified as road development and management increased. Following 1945, the use of aviation for delivering smoke jumpers and fire retardant quickly after the fire was detected made suppression of remote small fires particularly effective. Effects of livestock grazing on wildfire occurrence began in Idaho about 1880.

[2] The variation in Fire-Free-Intervals (FFI) is included within the data for most of the studies cited. The importance in variation is discussed in the text.

changes. Examples of successional conversion resulting from human-caused increase in FFI length include:

- curlleaf mountain mahogany to western juniper, Utah juniper, Douglas-fir, or white fir (Gruell 1983, Gruell et al. 1985)
- ponderosa pine to Douglas-fir, grand fir, or white fir (Weaver 1961, West 1969, Luman and Habeck 1973, Hall 1976, 1977, Davis et al. 1980, Gruell et al. 1982)
- Douglas-fir to white fir, grand fir, subalpine fir (Houston 1973, Arno 1980, Davis et al. 1980)
- lodgepole pine to Douglas-fir, subalpine fir, or grand fir (Brown 1975, Arno 1976, Tande 1979, Davis et al. 1980, Romme and Knight 1981, 1982)

- western larch to subalpine, grand fir, or cedar/hemlock (Marshall 1928, Arno 1980, Davis 1980)
- western white pine to grand fir, subalpine fir, hemlock, or western redcedar (Davis et al. 1980, Fischer and Bradley 1987)
- whitebark pine to subalpine fir (Arno 1986, Morgan and Bunting 1990)
- subalpine meadows to subalpine fir, Douglas-fir, or lodgepole pine (Dunwiddie 1977, Butler 1986)

What effects have the lengthening of FFI's had on vegetation stability, diversity, and resilience? Fire affects many biotic community processes and attributes other than succession (Brown 1975, Lyon and Stickney 1976, Davis et al. 1980, Gruell 1980, Heinselman 1981, Chandler et al. 1983, Gruell et al. 1986). These include: [1] fuel loads (Brown 1975, Davis et al. 1980), [2] nutrient and biomass cycling (Chandler et al. 1983, DeBano 1991), [3] energy flow (Kucera 1981), [4] species composition and physiognomy (Cattelino et al. 1979), [5] plant regeneration (Brown 1975, Cattelino et al. 1979, Lyon and Stickney 1976, Morgan and Bunting 1990), [6] forage quality (Hobbs and Spowart 1984, Seip and Bunnell 1975), [7] ecosystem stability and diversity (Loucks 1970, Taylor 1973, Habeck and Mutch 1973, Brown 1975, Habeck 1976, Arno and Davis 1980, Kilgore 1981), and [8] the development of community type mosaics (Lyon et al. 1978, Romme 1982, Romme and Knight 1982).

As an ecosystem develops successionally, interspecific interactions become more complex. A change in the abundance of one species can result in major changes in other species as well. Repeated catastrophic disturbance, or long periods without disturbance, result in the homogenization of vegetation structure over a large area. This will reduce many environmental refugia upon which some species may be dependent. In many areas the suppression of fires have predisposed the vegetation to these types of changes.

The total effect of fire suppression and subsequent vegetational succession on Idaho forests and woodlands results in a landscape with greater abundance of late seral stages, greater tree density, and less diversity—particularly gamma diversity, which is the diversity of a large area such as an island or landscape (Magurran 1988). These successional effects may have been countered in some locations by timber harvest or recent wildfires. Eight other secondary effects are listed below, and have been suggested by several authors (Weaver 1961, Habeck and Mutch 1973, Fahnestock 1974, Brown 1975, Gruell 1980, Arno 1980, Arno 1986, Harvey et al. 1992). However, studies elucidating the ramifications of these effects are few. Some effects which have been proposed but not verified for many vegetation types include:

[1] greater susceptibility to stress from factors such as insects, drought and pathogens,
[2] reduction in capability of meeting specific habitat requirements of animal and plant species,
[3] less resistance to the spread of disturbances such as insect epidemics and fire from one stand to another,
[4] reduced resilience following disturbance due to the lack of adapted species on-site and seed sources for the early seral species,
[5] modification of soil properties,
[6] changes in water and nutrient cycles,
[7] reduction of large woody debris input to riparian systems which contributes to stream nutrient levels and structure, and
[8] greater fire intensity due to increases in fuel loading or changes in community composition.

Discussion of the last of these proposed effects is provided in the next section.

Fuel Loading and Forest Health

Discussions of the importance of treating the symptoms of forest health problems usually include the hypothesis that dead trees provide more fuel that will lead to more intense fires. This idea has been proposed frequently but not scientifically verified. Fire scientist Steve Arno (1993) of the USDA Forest Service said the abundance of large and severe wildfires in the inland West since the 1970s suggests that attempts to eliminate fire have simply led to a pattern of large severe fires burning in heavy fuels.

Fuels accumulate in forests when the rate of vegetative production exceeds the rate of decomposition. This is the situation in many of the vegetation communities in the Inland West. Insect and disease epidemics contribute additional fuels (P. Morgan, review comments). The conventional wisdom as expressed by the USDA Forest Service dates back at least six decades (Clapp 1933):

> Insect-killed forests are a potential danger because of the existing fire menace. When extensive outbreaks of insects develop in forest types composed chiefly of one species of a tree a high percentage of the stand may be destroyed. These standing dead trees go down in the course of a few years making an almost impenetrable tangle of logs and tops. Under proper conditions a flash of lightning may set off the mass resulting in a widespread conflagration almost impossible to fight.

The logic of the dead trees/fuel loading/intense fires hypothesis is such that it may not need to be scientifically verified when there are more pressing research problems. Anyone who has tended a campfire or fireplace knows that the more wood you throw on, the larger the fire becomes, and that seasoned dry wood burns better than unseasoned freshly-cut wood because of the difference in moisture content. There can be no doubt that larger fires require greater and more intensive efforts to control them, and thus the expenditure of more resources.

Kimmins (1987, 1992) observed that forest ecosystems by definition are a fire hazard because they consist of large quantities of wood. Many forests owe their character to fire, including those in the northern Rocky Mountains. In some pine forests, low-intensity fires in the understory every few years almost "fireproofs" the forest by protecting the pine overstory. Except for a raging wildfire driven by dry summer winds, trees in these forest ecosystems are rarely killed by fire. But pine forests from which fire has been excluded for many decades may experience "explosive" wildfire events as the dense understory of herbs, shrubs, and young trees provides a "fire ladder" that can lead a low-intensity surface fire into the tree canopy, turning an environmentally benign fire into a destructive one (Kimmins 1987, 1992).

Arno and Brown (1989) provided evidence of "the folly of ignoring the buildup of wildland fuels." In 1985, 1,400 homes were lost to wildfires nationwide, with Florida and North Carolina hardest hit; dozens of homes were destroyed and thousands of others protected "at great cost" in northern California and Southwestern Oregon in 1987; and in 1988, $145 million was spent to suppress wildfires in the Yellowstone area to protect homes and multi-million dollar resorts. In addition to high suppression costs, severe fires are extremely costly to lives, property, and natural resources. A sensible fire management approach is to develop strategies for three different zones: wilderness and natural areas, general forest or multiple use management zones, and residential forests (Arno and Brown 1989).

Kimmins (1992) stated that the major ecological effects of fire are on the atmosphere, plant communities, animals, and on the soil, including soil animals and microbes. All of these act together to affect the ecosystem. Very hot summer and fall wildfires can affect forest ecosystems by removing much of the organic matter and causing the loss of some nutrients. These fires also affect soil by significantly reducing long-term site productivity through heat damage. Areas burned in large, hot wildfires may take centuries to reforest. However, the ecosystem may not be as badly damaged or set back in successional condition as first appears. Mobile animals, including many that live in the soil, usually escape the direct effects of fire, but end up losing habitat. The effects on the atmosphere are from smoke, which people object to, and from reduced vegetation, meaning that the ecosystem will not be removing as much CO_2 from the atmosphere (Kimmins 1992).

Fires also affect watersheds. Burning in riparian zones generally has negative effects on watershed quality. Stream nutrient regimes can be adversely affected for a short time, and reduced vegetation means reduced buffering capacity against overland sediment flow (Belt et al. 1992).

Beschta (1990) said fire has a great potential to alter water quality in streams draining forested watersheds. Potentially accelerated surface erosion on steep slopes is perhaps of most concern. Substantial increases in sediment yields can occur in steep terrain following a hot burn from wildfire (Beschta 1990). Increased sediment yields were found after a wildfire burned three relatively steep watersheds in ponderosa pine/Douglas-fir forests in the central Washington Cascades, primarily from increased susceptibility to debris torrents (Helvey 1980, Helvey et al. 1985). The unstable nature of steep slopes is such that overland water flow following fire is not a prerequisite for accelerated soil erosion. Soil can erode following fires through a process called dry ravelling, where it just slides down the steep slope (Beschta 1990).

Fires can occur with few adverse impacts and have little change on ecosystems. In fact, the exclusion of fires may be more of a problem than what fire suppression is supposed to remedy (P. Morgan, review comment). This leads to the idea that fire can be restored through prescribed burning.

Mutch (1993a) outlined a fire-based prescriptive strategy for forest health in the Blue Mountains of Oregon, with more detail provided by Mutch et al. (1993). The strategy developed by Forest Service scientists follows the basic principle of "Pay Now or Pay Later." The payments now include not only the costs of conducting prescribed burns and associated risks of escape, but also increased smoke and reduced visual quality from prescribed burning. The payments later, if action is not taken now, are not only costs of suppressing severe fires from fuel buildup if fires are suppressed, but ecosystem changes such as increased sediment loads in streams and reduced wildlife cover (Mutch 1993a).

Kimmins (1987) said the question whether or not the effects of increased fuel are ecologically damaging is not something that has been well-studied. Because the occurrence of fire has been greatly reduced in some ecosystems, conditions exist in which relatively benign natural fires have the potential to produce "widespread destruction." Fire can deplete organic matter and nutrient reserves, thus disturbing long-term ecosystem function (Kimmins 1987). According to Gray (1992b), William Gast, who headed the Blue Mountains forest health study (Gast et al. 1991), told *The Oregonian*, "Because fuel load is so high, a fire would burn so hot it could break down the structure of the soil and reduce soil productivity. That fact complicates letting nature take its course."

Botkin (1990) observed, as did Kimmins (1992), that sometimes the failure of the forests to regenerate may be a result of especially intense fires. Sometimes such fires follow timber harvesting, as happened more than a century ago in Michigan. Large areas of the region known as "stump barrens" in Michigan have failed to recover. Loggers took only the main trunks of the trees and left the rest in the forest. There was little concern about fire a century ago, and when fires accidentally started, the large amount of fuel from logging slash may have produced fires intense enough to consume much of the organic matter in the soil. The inability of the forests to recover from logging and subsequent intense fires may also result from a lack of seed-bearing trees, because few, if any, remained after logging and intense fires. These explanations are not based on rigorous scientific experiment. But rapid clear-cutting over such a large scale in such a short time, with little care taken for the treatment of the soil and the intensity, rather than the existence, of fires led to undesirable results. Smaller cuts scattered among intact stands, with care for the soil and the avoidance of erosion, could have been part of an ecologically sensitive approach (Botkin 1990).

Dr. John Osborn (1992a), a leading conservationist in the Inland Northwest, said unhealthy forests increase the risk of large fires:

> Forest ecosystems of the Northwest are sick, and some are in critical condition. While there is absolutely no room for indiscriminate burning,

> and while we must work to resolve problems with smoke and reduce the risk of conflagration, we also need to recognize the essential role of fire in restoring some Northwest forests to health.

Osborn's perspectives on forest health and fire come from careful study of the situation. He is a physician with a master's degree in forest fire ecology, and a student of fire history. In his essay on fire history in the region (Osborn 1992a), Osborn cited Flaherty (1972), who quoted William Beaufait, a Forest Service researcher:

> Society may choose to try to improve on nature; but to go blindly on, ignorant of nature's techniques is foolhardy. We must know all the consequences of what we are doing. On the other hand, we cannot let wildfires go where they will all of the time. Their cost and consequence would be beyond reason.

The quotation closed with an argument to allow some fires to burn themselves out. This is a position favored by wilderness advocates (Wuerthner 1988).

Forest health in the Inland West, however, is a different matter than maintaining natural conditions in parks and wilderness areas. Journalist Richard Manning (1992), writing in *High Country News*, conceded that fuel loads today across 25 million acres of national forest lands in the northern Rocky Mountains are such that if burned, the results would be a conflagration. Monnig quoted fire scientist Steve Arno, who said, "A severe, unnatural wildfire is not going to save the streams or riparian areas."

The Wilderness Society does not dispute the increased risk of catastrophic fire and its harmful consequences, but warned of the use of salvage sales to correct the situation (Aplet 1992):

> The most probable risk posed by the current situation is increased likelihood of catastrophic fire. The encroachment of fire-tolerant tree species has created a fuel ladder that threatens to spread inevitable fires to the crowns of overstory trees. Catastrophic fire would kill most of the existing vegetation and might lead to increased erosion and degradation of stream habitats.... Salvage logging has been proposed as a means of reducing fire risk by reducing fuel loads and severing the ladder to the canopy.... I have grave misgivings about the use of salvage sales to achieve this end.

Aplet (1992) offered no alternatives to salvage logging as a remedy for what he recognized as a potential problem.

Salvage logging is perhaps the most controversial of the many issues associated with forest health. The rationale for salvage logging is often associated with reducing the risk of catastrophic fire. The next chapter on salvage logging will further explore the linkage between the two.

Conclusions

Fire was a natural disturbance factor that shaped most of the vegetation communities in the Inland West prior to settlement by European Americans. Suppression efforts have excluded fire from its natural role, which often kept forests from following the process of succession through to the climax stage. Fire exclusion may have disturbed Idaho forest ecosystems more than natural, frequent fires. In addition to changed vegetation patterns, fire exclusion has led to increased fuel loads. It is generally recognized that this makes forests susceptible to severe wildfire.

Although the hypothesis that additional fuel in forests caused by trees dying from insect and disease epidemics will lead to more intense fires has not been scientifically verified, the proposition is widely accepted by forest ecologists, fire scientists, and many environmentalists.

Covington et al. (1994) concluded that there is a consensus among natural resource professionals that disruption of fire regimes and ensuing increases in tree densities, resultant catastrophic crown fires, and insect and disease attacks are a far greater threat to biological diversity and ecosystem sustainability than the general public realizes.

Chapter 8. Salvage of Dead and Dying Trees

Possibly the most controversial aspect of forest health management is whether or not dead and dying trees should be removed from a site. Any reason for salvage logging that does not protect a full range of forest values—trees, soils, wildlife, water, and scenery—is difficult to justify on public forests.

Idahoans want healthy forests (Idaho Forest Products Commission 1993). A public opinion poll in Idaho indicated most people (60%) agree that modern logging practices are ecologically sound, and a large majority (84%) agree that timber should be salvaged "where salvage makes sense" (Idaho Forest Products Commission 1993, Dan Jones and Associates 1992). We will try to make sense out of that statement in the closing section of this chapter, after we review the issues associated with salvage logging.

The Rationale for Salvage Logging

To assist with the control of pests and pathogens, salvage logging operations have traditionally been used to harvest dead and dying trees. Wood fiber that would otherwise deteriorate is salvaged, but salvage logging in the context of forest diseases treats only the effect and not the cause of problems. Salvage operations can help reduce forest health problems by removing dead, dying, or high risk trees, helping to make the stand less susceptible to catastrophic fire and insect epidemics. Great care needs to be exercised in salvage logging operations because of resulting soil compaction and the possibility of wounding residual trees (Filip and Schmitt 1990).

Salvage logging, according to Filip and Schmitt (1990), "is a bandage where in most cases surgery is needed." Surgery involves cutting into the affected area and repairing it. Without effecting a surgical cure, the area is likely to be reinfested. The cure involves managing appropriate species and numbers of trees that are resistant to low levels of disturbance and will be resilient following more severe disturbances.

Bandages have a short-term purpose in human health, so by analogy salvage logging may have a role in forest ecosystem health as well. Brooks (1992), of the Association of Forest Service Employees for Environmental Ethics said, "Salvaging may have a role to play in the ecological restoration of forests." She stated that timber salvage should not be the focus of the debate; instead, the "creation of functioning healthy ecosystems" should be the focus (Brooks 1992).

There are good economic reasons why dead trees should be removed expeditiously, and good environmental reasons why some dead trees should be left on a site. Analysis of an array of alternative levels and methods of salvage logging can assist in developing effective long-term strategies by focusing attention on the potential economic and ecological impacts of the decision to remove dead trees or leave them in the forest. Not all trees need to be removed to attain benefits; in fact, some should be left on the site for wildlife and soil purposes.

Economic Issues

Generally, timber salvage programs are undertaken to improve and protect timber stands. Salvage logging operations also recover the value of dead trees and remove live deformed ("cull") trees with split tops, broken tops or other structural defects that reduce stand growth and value. These trees are usually removed so they don't inhibit the growth of other trees, interfere with the establishment of a new stand, pose a safety hazard to forest workers or recreation visitors, or interfere with the use of equipment in subsequent stand entries.

Dying trees are removed to reduce the risk of future insect and disease epidemics (see additional discussion in Chapter 11). Brunson's (1991, 1993) survey research on ecosystem management acceptability showed that many foresters believe dead wood harbors disease pathogens and insects, acting as a bank to start the spread of new infestations.

The two principal economic reasons for removing dead and dying trees are that they have economic value, and they are a source of additional fuel for wildfires that can lead to increased costs of fire control.

Timber value and recovery. Salvage logging is not a new concept. In a report to the U.S. Congress 60 years ago, the USDA Forest Service (Clapp 1933) said that occasionally there are extensive stands of mature timber that have been killed by such agents as fire, insects, windthrow, and more rarely, introduced parasitic fungi. Killed timber rapidly deteriorates from checking, staining, wood-boring insects, and decay. The rate of deterioration varies with the tree species involved. Prompt removal and utilization of such timber is the only effective method of salvage. This is not always possible, either because of economic conditions or because the aggregate volume killed, while large, is so scattered that it cannot possibly be salvaged at a profit. Where bark beetles have done the killing, fungi that entered with the beetles are already established in parts of the sapwood by the time the trees die and stain begins shortly after death (Clapp 1933).

Across large areas, the rate at which trees are killed by insects and diseases is usually low and somewhat predictable. Little of this mortality is captured by harvesting because the dead trees are widely scattered and thus economic harvesting operations cannot be supported. But epidemic insect infestations, wildfire, and windstorms cause localized concentrations of timber mortality. Timber killed in catastrophic events is often salvaged and utilized for timber products (USDA Forest Service 1990b).

Dead trees have economic value if they can be harvested and processed into useful products before wood quality deteriorates, either from cosmetic fungus damage or physical damage caused by the wood drying out and checking or rotting from decay. The rule of thumb in southwestern Idaho is that if dead trees are allowed to stand for one year, they will lose half of their economic value (D. Van De Graaff, pers. comm).

Sampson (1992a) said that over the long term, we need to manage for healthier forests that are better able to withstand severe natural and human-induced stresses. The best way to do this is to manage our forests first as ecosystems, and second for their economic value and products. Sick forests quickly become an economic liability. Healthy forests are the only hope for sustainable forest economies, whether they are based on logging, tourism, or both (Sampson 1992a). Survey research by Walsh et al. (1990) in Colorado showed that the public places a high value on non-commodity values of healthy forests, and is willing to pay for protection programs.

Sampson (1992a) pointed out that the overriding goal must be the restoration of diverse and healthy forest ecosystems that can withstand the normal cycles of dry weather, as well as tolerate periodic fires without blowing up into a huge conflagration. In the process, there are millions of marketable logs that can be removed to help pay for the forest work, while creating many forest-related jobs and stimulating local economies (Sampson 1992a).

Cost of fire control. A persuasive argument for salvage logging is fuel management, defined as the manipulation, modification, and reduction of flammable vegetation to meet fire protection and land management objectives. Because the amount of flammable material is reduced in critical areas, fuel management is one of the most effective methods of "preventing high-intensity fires that are so damaging to natural resources and property" (Barney et al. 1984).

Dead trees increase fire risk by creating a more flammable fuel, and thus increase the cost of fire control. The mechanical removal of dead fuels through salvage logging is one of many fuel management techniques. The Forest Service estimated that by reducing fuel loads in the Blue Mountains, $4.3 million a year in fire suppression costs from normal fire-fighting budgets will be saved annually over a 20-year period. Even more will be saved from emergency suppression funds for large wildfires (Clark 1993b).

Social Issues

The salvage logging issue is as much about public trust in the USDA Forest Service and forest products industry motives as it is about forest health. To some environmentalists, "the proposed cure [of salvage logging] is worse than the illness" (Garber 1992). We will explore this issue further, with a wide range of views from Forest Service administrators and officials, forest products industry representatives, and a variety of environmental groups. The social considerations include economic, environmental and aesthetic values.

USDA Forest Service position. Associate Chief George Leonard (1992) said:

> The Forest Service is taking aggressive action to reduce the impacts of these forest health problems through increased salvage of dead and dying timber, direct control of the pests, and other short-term measures. We recognize, however, that these actions do not address the underlying causes of the problems.

Forest Service scientists (Mutch et al. 1993) believe that many stands of trees in the Inland West are excessively dense and as a result contain many dead and dying trees. Restoration to healthy forest conditions will therefore require different approaches from those needed to maintain forests that are in a healthy condition. Where large quantities of standing dead trees are present, "salvage logging should be used to remove unnatural accumulations of fuel and obtain wood products" (Mutch et al. 1993). Furthermore, careful salvage logging will help to mitigate resource damage that might occur from more intense fires, and may be a necessary prerequisite for removing unnaturally heavy accumulations of dead and dying trees before prescribed burning programs for restoring forest health can be initiated (Mutch 1993b).

Forest products industry position. Forest health is important to the forest products industry for two reasons. First, adverse changes in the health and productivity of forests could affect long-term timber supplies and the value of private timberland assets. Second, government reactions to forest health issues can restrict timber supplies, sometimes unnecessarily or excessively (National Council of the Paper Industry on Air and Stream Improvement 1993b).

In a point/counterpoint forum in the *Idaho Statesman*, Kohli and Shaul (1992) presented arguments for and against salvage logging. Shaul, whose affiliation was not identified, said, "Dead trees are the legacy for future forests. Leave them be." Kohli, an Idaho forest products industry spokesman, said careful road construction and in some cases helicopter logging can be the basis for an environmentally sensitive timber salvage program that will provide valuable raw material and give the remaining healthy forest a better chance for survival. Kohli emphasized the "need" to salvage dead timber before it deteriorates or is consumed by fire (Kohli and Shaul 1992).

The National Forest Products Association (1992) said, "while salvaging dead and dying timber is not the optimal manner in which to deal with forest health problems we face, these sales do help get some stand rehabilitation work completed." When interviewed by Garber (1992), Dave Van De Graaff of Boise Cascade Corporation in southwestern Idaho expressed more concern about the future condition of the forest than acquiring a short term glut of dead timber. He expressed pessimism about the future, because he doubts the Forest Service will be able to protect enough of southwestern Idaho's forest to produce timber on a sustained basis.

Environmental group guidelines. The benefits of salvage logging would seem to be a win-win situation from a forest health perspective. Quantities of flammable fuel are removed, reducing the potential of costly wildfires, and economic value is recovered. But not everyone agrees.

Environmental groups cite several objections to salvage logging. Some even say that salvage logging is just an excuse to help beleaguered national forest managers achieve their assigned allowable cuts. According to

Gray (1992b), environmentalists are worried that the Forest Service will use salvage logging as an excuse to enter roadless areas. Craig Gehrke (1993), of the Wilderness Society in Idaho, agreed, and also expressed concern that the agency can avoid doing environmental impact statements and administrative appeals of timber sales by using salvage logging to "get the cut out." Lawson (1993) said, "I'm cynical enough to think that this recent editorial effort ['more and more stories concerning forest health'] is appearing because there is a need to 'sell' timber salvage sales to the public as a necessary operation in order to maintain or enhance forest health."

Idaho Conservation League spokesman Mike Medberry said to Garber (1992) that the Forest Service doesn't have a clue what to do, so the agency does the only thing it knows how to do—cut down trees. In the same *Idaho Statesman* article, Ron Mitchell of the Idaho Sportsmen Coalition stated that the Forest Service looks at dying trees and only sees two-by-fours going to waste. Both stated a belief that the forest health issue is a ploy to open up roadless areas that the Idaho Conservation League has proposed for designation as wilderness. Indeed, Medberry said, "Salvage logging is the best excuse for the Forest Service to meet politically determined timber quotas.... At least six of the salvage timber sales [in the Boise National Forest] will be helicopter logged in roadless areas, disqualifying logged portions of these areas from future Wilderness designation." Gregory Aplet (1992), of the Wilderness Society in Washington, D.C., believed the forest health situation in the Inland West is being exaggerated in order to accelerate timber harvesting in the name of ecological restoration to compensate for harvest reductions on the westside of the Cascade Mountains.

In addition to the issue of distrust of Forest Service intentions is the issue of scientific uncertainty. Aplet (1992) acknowledged a compelling case for restoration and recognized catastrophic fire risk potential, but did not see any role for salvage logging. Because logging and fire management created the problem, he said it is "a bit hasty to conclude that logging and fire management will provide the solution." Larry Tuttle, of the Wilderness Society in Oregon, said, "You can never remove enough [dead timber] to change the fire picture" (Swisher 1993). Gehrke (1993) added, "Most conservationists remain unconvinced that salvage logging makes an overall healthier forest.... a quick and dirty fix of salvage and thinning might very well be the last thing [stressed forest ecosystems] need."

Gehrke went a step further than his Wilderness Society colleague Aplet, and provided recommendations for regulations to govern salvage logging. They are presented in Table 8-1 along with recommendations from two other environmental groups. Collectively, the environmental groups' view on salvage logging is to be careful.

Roy Keene (1993), a consulting forester and director of the Public Forestry Foundation in Eugene, Oregon, said there really is a forest health problem, and the real debate should focus not on whether there is a problem, but on what to do about it. He asked, "Can salvage logging cure the sick forest?" He didn't say yes or no, but offered six "well-proven historical standards" to guide salvage logging:

- Forest health salvage logging should rescue, save, or heal the site, not impact it further.
- Salvage activities should focus on preserving living and growing timber and promote younger growth, particularly in shade-intolerant species.
- Salvage activities should maintain or increase productivity as well as the capital value of the stand.
- Salvage harvesting should be efficient, yet not too rushed.
- Salvage activities should help reduce fuel levels and fire hazards.
- Salvage activities should not draw further from the forest without first protecting it.

Although Keene (1993) didn't say so, his guidelines remind one of the physician's adage, do no harm.

Scenic beauty. Research has repeatedly shown that dead and down wood affects scenic beauty judgments negatively, whether the wood is

Table 8-1. Timber salvage guidelines proposed by environmental groups.

Recommendation	AFSEEE[1] (Brooks 1992)	IEPLC[2] (Osborn 1992c)	The Wilderness Society (Gehrke 1993)
(1) Purpose of salvage	"Restoration forestry" to imitate nature's patterns and reestablish healthy forest ecosystem	consistent with recovery of forests, especially damaged watersheds and fisheries	institute meaningful ecosystem management programs
(2) Goal of restoration	... mimic pre-settlement conditions	restore fire—especially for fuels reduction	(none mentioned)
(3) Funding	should include other remedies—silviculture and prescribed fire	(none mentioned)	all revenue generated should be returned to U.S. Treasury
(4) Public input	public has a right to be involved in any proposed management program	restore a second level of review of administrative appeals	(none mentioned)
(5) NEPA documents	should include cumulative effects of all management activities	limit categorical exclusion to 100,000 board feet rather than current 1 million board feet	(none mentioned)
(6) Roadless areas	leave intact	(none mentioned)	no salvaging in roadless areas
Other miscellaneous recommendations	monitor quantity of wood removal	forest health legislation—nothing should supersede existing environmental laws focus on restoring damaged forests in Columbia River Basin	no road construction for salvage sales charge all salvage against allowable sale quantities no salvage logging on lands identified as unsuitable for timber production in national forest plans take only dead trees in salvage operations do not allow actual timber purchasers to mark and cut trees—USDA Forest Service or independent contractor should do it

[1] Association of Forest Service Employees for Environmental Ethics, Eugene, OR.

[2] Inland Empire Public Lands Council, Spokane, WA.

from harvesting and thinning activities or natural processes (Ribe 1989). The aftermath of dead trees left after insect infestations has been shown to reduce scenic beauty (Buyhoff et al. 1982). The visual condition of forests may become increasingly important to tourism-based economies. The challenge for foresters is to reduce the threat of insect and disease epidemics and extreme wildfires posed by dead and dying trees without creating adverse visual impacts. Salvage logging is one possible way to do this, but it must be done sensitively to reduce the visual effects of road networks and clearcut areas (M. Brunson, review comments).

Environmental and Ecological Issues

Ecosystem changes appear to follow a trend of forest succession, with gradual incremental changes over relatively long periods, periodically punctuated by rapid changes such as wildfires and insect and disease epidemics that significantly alter ecosystem structure and function. As ecosystem changes occur, they result in conditions that support some life forms, but are detrimental to others. These changing conditions also favor certain uses of natural resources by humans but preclude some other uses. Increases in tree mortality due to drought, insect epidemics, and wildfire can be viewed as an opportunity to provide wood fiber for human use. Salvage logging programs are necessary to take advantage of that opportunity, within constraints designed to maintain wildlife habitats, water quality, soils, and ecosystem productivity.

Wildlife habitats have been the subject of salvage logging debates. Sonner (1993) reported that environmental groups are opposed to salvage logging in old-growth forests that provide habitat for the protected northern spotted owl; the Oregon Natural Resources Council has stated that without dead and dying trees, old-growth ecosystems will not persist over time.

The fate of imperiled salmon stocks in the Northwest protected by the Endangered Species Act further complicates forest management (Titone 1992) and has been used to delay salvage sales in Idaho.

Wildfire can be beneficial for wildlife, but in managed landscapes altered by insect epidemics, wildfire can pose a threat to some wildlife habitats. Some of these areas may be isolated and serve as temporary refugia for species that cannot use the human-altered landscape until succession provides conditions more favorable for them. For example, pileated woodpeckers and red-backed voles appear to be dependent on old-growth forest stands. Most national forest plans call for the retention of 10% of the forested land base in old-growth habitat. Because of past management practices these stands are likely to be small and isolated. A large wildfire in adjacent insect- or disease-damaged second growth could consume these old-growth retention stands, possibly resulting in the local extinction of species dependent on the old-growth habitat. But this is not a rule, as wildfires on cooler and wetter sites leave patches of vegetation in the wake of fire.

Dead trees are a necessary component of forest ecosystem structure and serve a number of ecological functions (Davis 1983, Maser and Trappe 1984). These necessary functions temper arguments for excessive salvage logging. Two of those functions—wildlife habitat and soil productivity—have been examined in detail and definitely pose constraints on salvage logging operations. Dead trees provide habitat for wildlife, insects, fungi, and many other organisms. This includes standing dead trees, usually called snags, and dead and down woody material (Thomas 1979, Maser and Trappe 1984, Brown et al. 1985). Cavity nesters use standing dead trees, and burrowers use downed woody material (Gast et al. 1991). In addition, downed woody debris of all size classes is necessary to maintain the long-term productivity of forest soils (Edmonds 1991).

The following subsections review the functions of dead trees as wildlife habitat and soil components, with specific attention on guidelines for snag retention and "leave" trees for supporting these functions.

Wildlife snags. Snags have been defined as any dead tree or partly dead tree that is at least 6 feet tall and 4 inches in diameter at breast height (Thomas et al. 1979). Cull trees are sometimes included in this definition (Neitro et al. 1985). Snags are classified as either hard or soft, and some wildlife can use only one or the other type. Hard snags are usually marketable, with some sound wood, usually on the outside. Soft snags have little economic value and are in advanced stages of decay.

The importance of snags, or standing dead trees, to wildlife has long been recognized (Bull 1978, Bull and Meslow 1977, Davis 1983). Snags provide essential habitat for 85 species of North American birds, and at least 49 species of mammals. Snags and fallen trees are also used by a variety of amphibians, reptiles, and invertebrates (Davis 1983). In the Blue Mountains of eastern Oregon and Washington, 39 species of birds and 23 mammals use snags for nesting or shelter (Thomas et al. 1979). In western Oregon and Washington, about 100 species of wildlife use snags, with 53 species (39 birds and 14 mammals) dependent on cavities in snags (Neitro et al. 1985).

Wildlife use snags to meet a variety of behavioral and physiological needs. Davis (1983) listed more than 40 uses of snags, including nesting, foraging, roosting, hiding, displaying, and grooming. Similar relationships occur between wildlife and snags in Idaho. The importance of snags is reflected in the designation of snag-dependent wildlife as management indicator species by the USDA Forest Service (see Chapter 9).

Research on snag use and the management of forests for snags has largely focused on birds that use cavities in snags as nest sites (Balda 1975, Bull and Meslow 1977, Scott 1978, Thomas et al. 1979, Neitro et al. 1985). Cavity nesters can be divided into primary users—birds such as pileated woodpeckers and common flickers that excavate cavities in snags—and secondary users, including nuthatches, chickadees, and some owls that use cavities abandoned by primary excavators or cavities formed by decay or limb breakage. Morrison and Morrison (1983) documented declines in populations of three woodpecker species over a 30-year period in the Pacific Northwest and suggested that declines coincided with an increase in intensive forest management practices that eliminated snags from large areas. To make snag management more practical, researchers reasoned that by providing for primary cavity nesters that use hard snags, and by retaining all soft snags, the needs of all snag-dependent species would be met (Bull 1978, Thomas et al. 1979)

Snag guidelines. Based on assumptions about the useful life of a snag, snag recruitment rates, and wildlife use of snags, guidelines have been developed for snag management in the Blue Mountains (Thomas et al. 1979) and the forests of western Oregon and Washington (Neitro et al. 1985). Implementing the guidelines requires that managers first determine a viable population level—that is, a percent of maximum potential population—for snag-dependent species by forest or habitat types. Tables are then used to determine the density of snags necessary to maintain that population level, which is expressed as a number of snags by size class per unit area. For example, managers may set a goal of maintaining 70% of the potential maximum population of pileated woodpeckers in ponderosa pine stands. This would require the retention and recruitment of about 4 snags per acre of at least 10 inches diameter at breast height in ponderosa pine forests in the Blue Mountains (Thomas et al. 1979).

Not all snags are of equal value to wildlife. As previously stated, some wildlife prefer hard snags and others use only soft snags. Another important consideration is tree species. Ponderosa pine, larch, Douglas-fir, aspen, cottonwood, and willows are used most often by wildlife in the Blue Mountains (Thomas et al. 1979). In addition, large snags are used more extensively than smaller snags, and larger species, such as pileated woodpecker, require large snags.

The distribution of snags across a landscape is another issue in snag management. Most guidelines state that snags need to be well dispersed, but need not occur on every acre.

In addition, snags that occur in clumps are preferred by some species (Bull and Meslow 1977) and offer some practical management advantages (Styskel 1983). The use of riparian buffer strips to meet snag management goals is appealing, but found to be inadequate in western Oregon (Cline and Phillips (1983). Other snag management issues include: [1] monitoring snag abundance, [2] timber yield reductions, [3] data on snag longevity, [4] protection of snag and live replacements from premature loss, and [5] safety and logging operation conflicts (Styskel 1983, Neitro et al. 1985). Public attitude issues may also arise, as research has shown snag creation reducing the perception of scenic and recreational quality in western Oregon stands (Brunson 1991).

Retention of snags and maximum production of wood fiber are divergent goals (Jackman 1974). On the Deschutes National Forest in Oregon, estimated yield lost due to live tree retention for snag recruitment was as high as 12% due to seedling inhibition (Styskel 1983). A loss of 4% of the timber volume that could be harvested was determined by Menasco (1983) for the Tonto National Forest in Arizona due to snag recruitment and retention. Five primary cavity nesters inhabit the Tonto. To meet the goal of 50% of the maximum potential populations, two green trees and approximately two snags of 20 inches diameter at breast height were needed per acre.

Snags pose a safety problem for forest workers (Brunson 1991) and can interfere with the use of various types of equipment used with current silvicultural and logging systems. However, Neitro et al. (1985) discussed snag considerations in detail for clearcuts, partial, and intermediate cuts in tractor, skyline, and helicopter logging situations. In addition, government agencies and private organizations in the state of Washington have developed guidelines for selecting reserve trees for snag or snag recruitment that are updated annually (USDA Forest Service 1992c).

Fallen trees and soil. Dead and down woody material on the forest floor, along with woody material that has been incorporated into the soil, is an important component of forest ecosystems. Woody material appears to have three primary functions: [1] providing habitat for vertebrates, invertebrates, vascular plants, bryophytes, fungi, etc., [2] cycling nutrients, and [3] soil development and productivity (Maser et al. 1979, Maser and Trappe 1984, Bartles et al. 1985). Relative to snags, less is known about the recruitment of woody material to the forest floor and the amounts necessary to maintain ecosystem processes in managed forests.

Dead and down wood results from snag decay, windthrow, heavy snows, avalanches, landslides, floods, and other causes. Additionally, logging operations usually result in large amounts of relatively fine woody material on the soil surface. This logging slash is usually treated in some manner, such as piling and burning or broadcast burning. The primary concern here is the role of large decaying logs in the forest and how to provide for that in managed forests. Large diameter logs function differently than smaller material.

Fallen trees go through recognizable stages of decay and can be assigned to one of five decay classes (Maser et al. 1979). Each decay class functions in a number of different ways. For example, a recently fallen green tree may serve primarily as cover for small mammals. Wood-boring insects soon gain access to the tree and introduce decay-promoting fungi. As the tree decays, the bark sloughs off, moisture retention increases, other invertebrates colonize the log, small mammals eventually are able to burrow into the log, plant seedlings may become established ("nurse logs"), and eventually the wood becomes incorporated into the soil. These interactions are numerous and complex (Maser and Trappe 1984). Two of the most important aspects of fallen logs are their high moisture-holding ability and capacity as sites for nitrogen fixation by nonsymbiotic bacteria (Bartles et al. 1985).

Large trees on the forest floor can persist for centuries and provide a source of habitat continuity over time in harvested forests. Estimates of downed coarse wood on the forest floor in old-growth stands in western Oregon and Washington ranged from 25 to 259 tons per acre (Grier and Logan 1977). Logging slash from harvests in westside old-growth forests ranged from 100 to 200 tons per acre. However, harvesting second growth timber resulted in 70% to 90% less residue than old-growth stands (Bartles et al. 1985).

Natural recruitment of fallen logs was estimated to be 0.5 trees per acre per year in an old-growth Douglas-fir stand in western Oregon (Grier and Logan 1977). Researchers have estimated that fallen trees constitute about 50% to 60% of the annual litterfall in old-growth (Grier and Logan 1977, Sollins 1982). In addition, about 10% to 12% of the forest floor is covered by large woody debris in these stands (Maser et al. 1979).

In the northern Rocky Mountains, wood in the soil is important for a number of reasons including: [1] reducing soil compaction, [2] as a source of organic material to the mineral soil, [3] as a site for nitrogen fixation and storage, [4] as a substrate for ectomycorrhizae, and [5] because of its high water content and physical characteristics, it supports root systems of living trees (Graham et al. 1991). A study showed down woody material averaged 21 tons per acre (range: 13 to 33 tons) in inland forests west of the Continental Divide and 14 tons per acre (range: 5 to 23 tons) in forests east of the Divide (Brown and See 1981). In western Montana and northern Idaho, Harvey et al. (1989) found that woody residues in the soil—not to be confused with woody material on the surface—averaged 16 tons per acre (range: 5 to 69 tons). This wood is incorporated into the soil horizons in the form of brown cubicle rot (Graham et al. 1991). In addition, decayed wood averaged 31% (range: 2 to 51%) of the soil organic horizon in undisturbed stands, and 25% (range: 14 to 39%) in disturbed stands (Harvey et al. 1989).

Woody debris guidelines. Managers need to consider the role of soil in silvicultural systems, and the role of downed woody material in maintaining soil productivity. Soil characteristics influence the choice of harvest and regeneration method (clearcut, shelterwood, or selection) and post-harvest treatments. Published recommendations for the northern Rocky Mountains suggest that following harvesting, site preparation, and hazard reduction treatments, 10 to 15 tons per acre of large woody debris that is greater than 3 inches in diameter should be left on a site (Harvey et al. 1987, Graham et al. 1991). How this material is to be distributed over a site is also an important consideration. Bosworth (1989) noted that seedling growth in northern Idaho was closer to maximum potential in clearcuts where residues were broadcast-burned rather than tractor-piled and burned, suggesting that residues should be dispersed across the site.

Mandzak and Moore (1994) stated that effects of harvesting and slash disposal treatments vary widely depending on site conditions and the specific site treatments. The key point is that nutrients are most concentrated in the fine branches and needles. Bole wood or logs are relatively low in nutrient content. Whole tree harvesting is a process by which whole trees and attached crowns are transported to landings for processing and disposal. This process can result in significant export of nutrients, which ultimately may need to be replaced by fertilization. Follow-up slash disposal can have a great impact on nutrient capital as well, particularly if very intense slash fires volatilize nitrogen from the slash, duff, and upper soil horizons. Dozer and windrow piling prior to burning localizes nutrients, making access to nutrients for the next stand unevenly distributed. Brockley et al. (1992) and Kimmins (1977) provide comprehensive reviews of these topics (Mandzak and Moore 1994).

Logging debris can form a barrier for some species of wildlife such as deer and elk. Unabated logging slash as well as large accumulations of deadfall in untreated stands can affect elk behavior and movement. Elk use may be diminished when slash inside a treatment unit exceeds 1.5 feet in depth and dead and down material outside the opening exceeds 1.5 feet (Boss et al. 1983). Two studies (Maser et al. 1979, Bartles et al. 1985) provided guidelines for the retention and distribution of woody debris on a site following logging that will enhance the area as wildlife habitat. These include, among other things, suggestions for slash size and depth, when to create windrows, and how long the rows should be.

Logs are also important components of aquatic ecosystems and provide a number of important structures and functions affecting stream morphology, nutrient cycling, invertebrate habitats, and fish habitats (Maser et al. 1988). These interactions are as numerous and complex as those in terrestrial ecosystems. Maser et al. (1979) and Bartles et al. (1985) presented a number of considerations and guidelines concerning woody debris in streams in managed forests. Maser and Trappe (1984) and Franklin and Maser (1988) identified a number of management and research directions for the near future.

The incorporation of riparian buffer strips into logging operations to maintain water quality and fish habitats is widespread in the Northwest, and one of the purposes of buffer strips is to provide woody debris in streams. Research data currently are inadequate to provide general guidelines as to how much woody debris should be available in the buffer strip or how much is required in a given stream (Belt et al. 1992).

Where does Salvage Logging Make Sense?

Salvage logging makes sense if timber stands can be improved and protected without sacrificing other forest ecosystem components, including soil, water, and wildlife. That means these other forest values need to be protected during salvage logging operations.

Economics also need to be considered along with ecological values. Salvage logging can recover economic value of dead trees, but that value can deteriorate fairly rapidly. Pre-approved salvage logging guidelines for public forests, perhaps developed through the forest planning process and expressed as standards and guidelines, seem to be a sensible approach. However, it will be several years before some national forests will be able to develop these standards and guidelines and the dead trees and their causal agents are in the forests now. Allowing salvageable quantities of dead trees to remain in the forest creates conditions that put all forest resources and values at risk of large and intensive wildfire.

According to a USDA Forest Service planner (Hayes 1993), despite an apparent large volume of timber that dies annually in north Idaho, little of it occurs in small enough areas with amounts likely to make large-scale salvage feasible. As with so many aggregated timber statistics, it is not the volume of dead merchantable sawtimber that exists, but where it is located that is important. It would be much more significant to know the mortality rate in sawtimber size trees on lands with less than a 40% slope near roads and where watershed or wildlife habitat conditions satisfy forest plan standards and guidelines than to know the mortality rate forest-wide. Furthermore, because most mortality in northern Idaho is associated with endemic levels of root disease, a large salvage effort would not be possible or prudent without a significant inventory and analysis effort entailing a major shift in management direction (Hayes 1993).

Where and when does salvage logging make sense? Insect and disease epidemics create situations where large enough volumes of dead timber occur to make salvage operations economically feasible. As long as other environmental and ecological values are not impaired, the fire hazard posed by dead timber can justify timber salvage from an ecological point of view.

Conclusions

Salvage logging can be a useful short-term bandage to protect forest ecosystem values while long-term solutions to forest health problems are being developed and implemented. Large quantities of dead trees put remaining live trees at risk of intense wildfires. In addition to live vegetation, wildlife and watersheds as well as soil nutrients and organic matter can be adversely affected by intense wildfire.

Salvage logging must be done with ecological and environmental sensitivity. Published guidelines indicate there is sufficient information to develop timber salvage standards and guidelines. Enough material (10 to 15 tons per acre) should be left on the site to provide benefits for soil formation and wildlife habitat. Development of planning guidelines for timber salvage from national forests would seem to offer a more socially acceptable approach to timber salvage operations than the current categorical exclusion from NEPA analysis and the exemption from appeals used recently in southwestern Idaho (see Chapter 16).

When accomplished with sensitivity to ecological, environmental, and scenic values—such as the use of helicopters in roadless areas—salvage logging has economic and environmental benefits that recommend the practice as a short-term solution to some forest health problems. Long-term considerations such as species composition, especially on sites where root disease exists, need to be addressed along with salvage logging in a comprehensive approach to forest health management.

Chapter 9. Wildlife and Forest Health

Wildlife are an integral part of any forest. Forests are not static and changes in forest structure and species composition will favor certain species of wildlife and deprive others of some elements necessary for reproduction or survival. For example, the effects of the current outbreak of the Douglas-fir tussock moth on forest structure could be beneficial to some cavity-nesting insectivorous birds, but may initially reduce thermal and hiding cover for elk. With time, however, increased production of grasses, forbs and shrubs may favor elk, but as snags decompose and fall to the ground populations of cavity-nesting birds may decline. At the same time, increased woody debris on the ground may favor bears, some small mammals, amphibians, and a variety of insects (Maser and Trappe 1984).

These types of interactions make a general discussion of wildlife in the current context of forest health difficult. As seen in the Blue Mountains of Oregon and Washington, wildlife concerns in relation to forest health have been reduced to developing guidelines for featured species (Gast et al. 1991). This includes enhancement of hiding and thermal cover for elk and deer as part of forest restoration activities, and managing the road system to control access to influence elk and deer mortality rates (Caraher et al. 1992).

The effects on fisheries are likely to be just as dynamic and varied. Initial increases in water temperature and sedimentation due to loss of canopy cover may be detrimental to some species. However, fallen logs play an important role in maintaining fish habitats (Maser et al. 1988).

Management Indicator Species (MIS)

Some wildlife species may serve as indicators of forest conditions. Forest Service regulations for implementing the mandates of the National Forest Management Act of 1976 directed the national forests to identify management indicator species (MIS) to facilitate forest planning and management (Wilkinson and Anderson 1987). Each forest in Idaho has identified a set of MIS (wildlife, fish, and plants) with descriptions of what the species are supposed to indicate (Table 9-1).

There is considerable debate concerning the usefulness and validity of the indicator species concept (Verner 1984, Landres et al. 1988, Noss 1990). Many of the criticisms of the indicator species concept are evident in Table 9-1, including: [1] vague definitions of what the species are supposed to indicate, such things as population trends in other wildlife species or habitat abundance and quality are among the possibilities; [2] selection of species that are too general; and [3] the inclusion of threatened and endangered species based only on that special protected status. Landres et al. (1988) identified major problems with the use of indicator species as the lack of rigorous and consistent selection criteria, the failure to address management goals as related to MIS's, and the lack of empirical data supporting the assumptions concerning MIS's. In most instances, there is no evidence that a particular MIS actually reflects trends in the populations of other species or habitat quality and abundance. Although the application of the MIS concept has problems, managing for wildlife habitat diversity by maintaining well distributed, viable populations of wildlife is a formidable task. Given the complexity of wildlife habitat relationships and population dynamics, and the richness of wildlife species on the national forests, the MIS concept was deemed the only feasible alternative.

Most national forests in Idaho have specified MIS's as indicators of specific habitat types (e.g. old-growth forest), particular habitat elements (e.g., snags), or both (e.g., pileated woodpecker). Although implicit in the MIS concept, only the Challis and Payette National Forests specifically made reference to MIS's as surrogates for other wildlife species, and then in the context of habitat. Although the different roles of MIS's as indicators of habitat abundance, habitat quality, or other wildlife species population trends can be subtle, the distinction must be made in order for the concept to be useful (Landres et al. 1988).

Many national forests in Idaho identified some species as MIS's because they were high

Table 9-1. USDA Forest Service management indicator species, their purpose, and associated national forest in Idaho.

Species	Indicates[1]	National Forest
Birds		
Bald Eagle[2]	Large rivers and lakes	Panhandle, Clearwater, Payette, Nez Perce, Caribou, Targhee
Goshawk	Old-growth, multi-layered mature stands on north slopes for nests, seral habitats for foraging	Panhandle, Clearwater, Nez Perce, Caribou, Targhee
Peregrine falcon[2]	N/A	Payette, Nez Perce, Clearwater
Great gray owl	Mature sub-alpine fir and Douglas-fir forests	Salmon
Sage grouse	Sagebrush habitats, range condition	Sawtooth, Caribou
Sharp-tailed grouse	Grass-shrub habitats, range condition	Sawtooth
Pileated woodpecker	Large snags, old-growth forests, old-growth species, cavity nesters	Panhandle, Clearwater, Nez Perce, Payette, Sawtooth, Boise, Salmon
Hairy woodpecker	Snags	Caribou
Lewis woodpecker	Riparian woodlands, large snags	Sawtooth
Williamson's sapsucker	Cavity dependent species, mature forest snags	Payette, Targhee
Yellow-bellied sapsucker	Cavity nesters, aspen	Caribou, Salmon
Belted kingfisher	Riparian habitat	Clearwater
Vesper sparrow	Non-forests, early succession species, sagebrush habitat	Payette, Salmon
Brewer's sparrow	Sagebrush habitats, mid-seral sagebrush	Sawtooth, Targhee
Yellow warbler	Riparian willow habitat	Challis, Boise
Pygmy nuthatch	Cavity nesters, old-growth ponderosa pine forests	Salmon
Brown creeper	Cavity nesters, mature sub-alpine fir and lodgepole forests	Salmon
Mountain bluebird	Cavity nesters, ecotones	Salmon
Mountain chickadee	Smaller snags and insects	Boise

(continued)

Table 9-1. USDA Forest Service management indicator species, their purpose, and associated national forest in Idaho (continued).

Species	Indicates[1]	National Forest
Mammals		
Grizzly bear[2]	Large undisturbed areas	Panhandle, Clearwater, Nez Perce, Payette, Targhee
Gray wolf[2]	Human disturbance	Clearwater, Payette, Nez Perce
Woodland caribou[2]	Climax forest vegetation	Panhandle
Elk	General forest seral species, habitat interspersion, coniferous forests, riparian forests, wet meadows, sagebrush-grass habitats, savanna forests, spruce-fir forest, sub-alpine fir-Douglas fir forest, summer range	Panhandle, Clearwater, Nez Perce, Payette, Sawtooth, Challis, Salmon, Boise, Targhee
Moose	Mature timber stands, pacific yew	Panhandle, Clearwater, Nez Perce
White-tailed deer	Interspersion of cover and forage, mature and old-growth, winter range	Panhandle, Clearwater
Bighorn sheep	Alpine, subalpine, rock-scree, open timber, rock outcrop habitats	Nez Perce, Challis, Targhee
Antelope	Sagebrush habitats	Targhee
Mule deer	Conifer forest, mountain brush, sagebrush-grass, savanna forest, riparian subalpine, Douglas-fir habitats, successional summer and winter range	Sawtooth, Challis, Salmon, Boise, Caribou
Mountain goat	High elevation, alpine, subalpine, rock-scree, open-timber, cliff habitats	Sawtooth, Challis, Salmon, Targhee
Pine Marten	Mid-to high-elevation mature forests, ecosystem health, old-growth sub-alpine fir and lodgepole forests	Clearwater, Salmon
Beaver	Riparian habitat	Targhee
Pika	Alpine, talus habitats	Targhee
Red squirrel	Climax or mature conifer forests	Challis
Red-backed vole	Old-growth forests	Boise

(continued)

Table 9-1. USDA Forest Service management indicator species, their purpose, and associated national forest in Idaho (continued).

Plants		
Big sagebrush	Increases > 20% = declining range condition	Challis
Bitterbush	Winter forage	Challis
Bluebunch wheatgrass and Idaho fescue	Climax range	Challis
Yarrow and thistle	Riparian disturbance	Challis
Aquatic insects	Water quality, litterfall and sedimentation	Challis Targhee
Fish		
Cutthroat, rainbow, and bull trout	Water quality: cool, clear, sediment free, streamside cover, instream flows	Panhandle, Clearwater, Challis, Salmon, Caribou, Targhee, Boise
Steelhead	Open channels, spawning gravels	Clearwater, Challis, Salmon, Boise
Chinook salmon	Same as steelhead	Clearwater, Challis, Salmon, Boise

[1] Many of the National Forests have the same species listed as an MIS. However, that species may indicate different things on different forests. This column lists those indicator attributes as identified in the forest plans, but does not associate each attribute with each individual forest.

[2] Designated a threatened or endangered species by the USDA Fish and Wildlife Service under the Endangered Species Act. NFMA regulations automatically made threatened and endangered species MIS's.

priority species of the Idaho Department of Fish and Game. Some examples include elk, moose, bighorn sheep, and white-tailed deer. As in the case of elk, this criterion may result in a MIS that is indicative of everything, and thus does not indicate much of anything. Similarly, automatic inclusion of endangered and threatened species as MIS's also seems unwarranted. These species may need special consideration in management planning, but they are probably too rare, too hard to monitor, or their habitat and interspecific relationships too poorly understood to be of much value as indicator species.

Numerous species of wildlife undoubtedly are instrumental in maintaining the integrity or health of forest ecosystems. However, relatively few of the many possible relationships have been documented. A classic example is the California red-backed vole, which uses fallen trees for cover and eats truffles. The vole is a primary disperser of truffle spores and the truffles need a host tree with mycorrhizal fungi for energy. The tree needs the mycorrhizal fungi for nutrient uptake and ultimately provides the rotten bole needed by the vole for cover (Maser and Trappe 1984).

Birds as Regulators of Insect Populations

The role of birds in regulating populations of insects that cause tree mortality is pertinent to current forest conditions in southern Idaho and the Blue Mountains. Birds consume large numbers of defoliating insects (Crawford et al. 1983). Takekawa and Garton (1984) estimated that without bird predation, spruce budworm populations would reach epidemic densities every three years in the Pacific Northwest, whereas actual epidemics occur about every 28 years (Dolph 1980). However, bird predation is most effective at endemic insect levels. Crawford et al. (1983) found that the percentage of spruce budworm larvae and pupae eaten by birds declined from 87% to 2% of the budworm population at endemic and epidemic levels, respectively, in northern New England.

The results observed by Crawford et al. (1983) are consistent with the Type II functional response of predators described by Holling (1959, 1965). That response is characterized by increasing prey consumption by predators as prey abundance increases, up to a threshold where predator intake reaches a point where the predators become satiated or swamped, and prey populations escape regulation and reach epidemic levels. This is illustrated in Figure 9-1, where lines A and B illustrate relationships at high and low densities of predators, respectively. The location of the line labels A and B is the approximate point where predator efficiency reaches the asymptote and the prey may escape any population regulation due to predation.

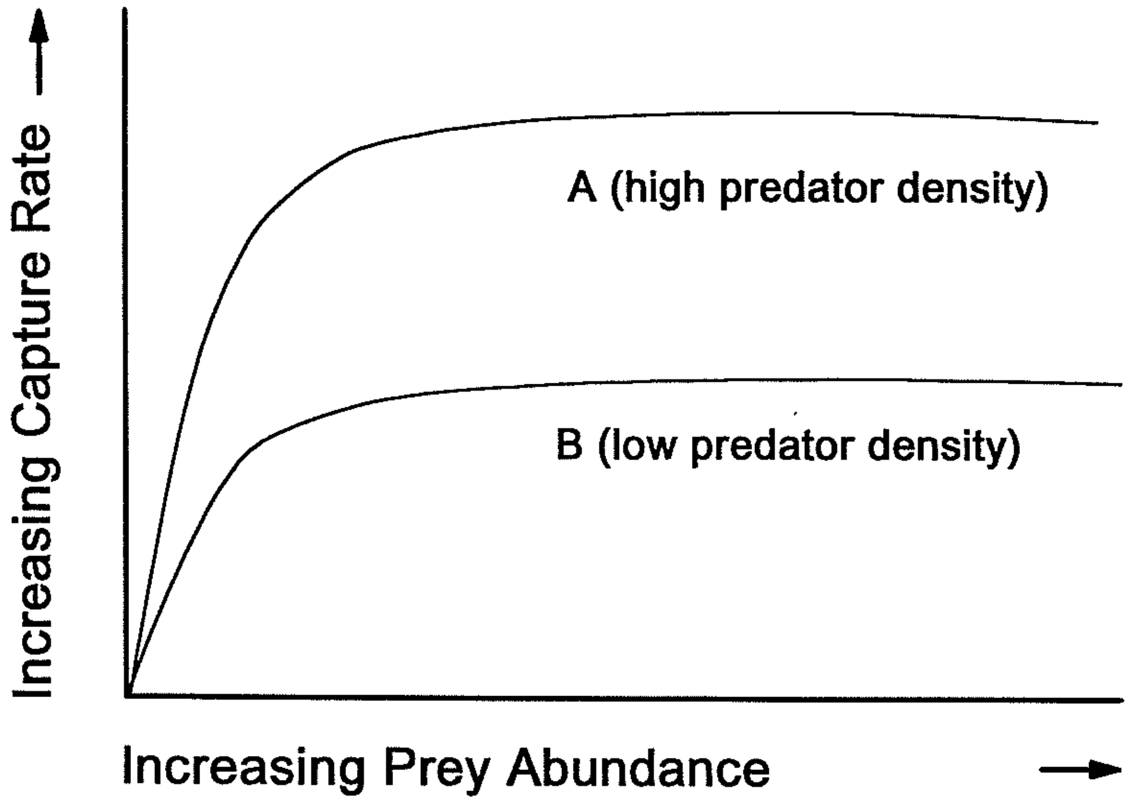


Figure 9-1. Predator-prey type II functional response.

In the context of the current situation, there may be two conditions that have allowed defoliating insects to reach epidemic levels in the context of avian predation. It has been suggested that recent declines of neotropical migrants—birds that nest in North America and winter in Central or South America—may have contributed to the problem. This is illustrated in Figure 9-1 by line A, indicating high populations of birds, and line B, indicating lower bird populations. At low predator densities the overall intake of insects by birds is lower and the insect population density at which they escape regulation is also lower. However, evidence suggests that most populations of neotropical migrants in the northern Rocky Mountains are stable or increasing (Line 1993). Data on population trends for about 55% of 119 migratory landbirds in Idaho indicated that seven species (6%) have significantly declined, another 26% exhibited non-significant population declines, while 22% of Idaho's migrants increased in population, but only 2% significantly (Saab and Groves 1992). Additionally, there is some evidence that resident insectivorous bird populations, e.g. chickadees and nuthatches, have declined over the past few years (E.O. Garton, pers. comm.).

Another situation that may have facilitated the insect outbreak, in relation to bird predation, is related to habitat characteristics. Holling (1993) explained it well:

> Essentially agents like insectivorous birds (Holling 1988) inhibit outbreaks whenever budworm populations are very low and the [tree] crowns are sufficiently small that searching by birds is concentrated within a small volume of foliage per hectare. Gradual growth of the trees and closure of the crowns forces searching activity by birds to be diluted over such large volumes of foliage that predation mortality declines and budworm populations escape to generate a spreading outbreak.

In the long run, density dependent mechanisms such as territoriality may not allow bird populations to keep pace with insect populations. It is possible that the declines in some bird populations together with increased density and cover of host trees were contributing factors in the current outbreak of Douglas-fir tussock moths in the forests of southern Idaho.

Conclusions

Wildlife are an integral part of forest ecosystems. The diversity of wildlife species and their different habitat requirements make their direct use as indicators of ecosystem health difficult.

Chapter 10. Ecosystem Management and Forest Health

Ecosystem management, although ill-defined, intends to be many things and offers many promises. This chapter reviews the meaning of ecosystems, what the concept of ecosystem management offers, and how forest health is related to ecosystem management. As a philosophy, ecosystem management has been fully embraced by federal resource management agencies. Haskell et al. (1992) pointed out that discussions of ecosystem management are now part of the public debate and scientific debate regarding the proper goals for environmental management.

Forest health is part of the ecosystem management dialogue. George Leonard (1992), Associate Chief of the Forest Service, in testimony before the U.S. Congress said:

> Forest health is directly related to ecosystem management. This new approach of the Forest Service gives greater consideration to the role that natural ecosystem processes and functions, such as fire, insects and pathogens, play in maintaining forest productivity and health.

The Forest Service is in the midst of a fundamental shift from the concept of managing forests for a variety of outputs to the concept of sustaining ecosystems that will meet people's needs (Monnig and Byler 1992). Under the guidance of ecosystem management, the Forest Service is moving in a new direction, where the health of the forest is more important than how many logs go to the mill (Barnard 1992). A goal implicit in ecosystem management is to re-establish and maintain the health and productivity of forest ecosystems (Leonard 1992).

The concept of forest health is new and meshes with emerging ideas about ecosystem management. Many people have embraced these concepts, perhaps because they are ambiguous and therefore provide short-term flexibility. That will likely change as Forest Service scientists and resource managers grapple with the task of replacing ambiguity with specificity. What they do on the ground and in their meetings with the public and with interest groups will ultimately determine public acceptance of the intertwined concepts of forest health and ecosystem management in the quest for sustainable forest ecosystems.

Ecosystem management, according to Assistant Secretary of Agriculture Jim Lyons, is a developing concept (Hopps 1993). Ecosystem management has as a primary goal the protection of ecosystem functions and processes that frame inherent productivity and resiliency (Cornett 1993). This is also a primary goal of forest health (R. Everett, review comments).

Ecosystem management, said Leonard (1993), requires an understanding of the interaction and influences of all species and all natural phenomena in a particular ecosystem along with understanding of human interests as well. It also requires taking into account both a much longer view of time, and a larger spatial scale (Leonard 1993).

The deans of five of the leading forestry schools in the nation raised eight points they believed the Forest Service needed to address in its shift towards an ecosystem management policy. One was a concern that emphasizing ecosystem management will shift management strategies toward biological outcomes and away from social and economic criteria. This will create higher levels of uncertainty for those dependent on traditional commodity outputs, and blur the distinctions between the national forests, with a mandate to balance economic and environmental considerations, and other public lands managed by other federal agencies with more limited purposes (Skok et al. 1992).

A task force of the Society of American Foresters (Norris et al. 1993) stated that ecosystem management is not the replacement of the production of goods and services with preservation of some natural state. Instead, it recognizes that natural disturbance regimes and ecosystem processes provide the basic blueprint for a sustaining pattern and process across the landscape. Furthermore, the task force pointed out that, ecosystem management focuses on achieving a desired forest condition—including the goals of maintaining linkages and processes, landscape patterns, and soil productivity. It allows for the production of goods and services within constraints posed by maintaining the integrity of the forest ecosystem. It explicitly embraces the human element, and recognizes that objectives and plans for forest management should be based on public values and public input to the decision making process (Norris et al. 1993).

Norton (1992), a philosophy professor, made an important point by insisting that all parties must enter the interdisciplinary dialogue. Environmental management, in Norton's view, is basically a policy discipline, where conservation biology, social sciences, and the humanities interact in the public debate regarding conservation goals, practices, and standards. He said resource management must have as a central goal the protection of ecosystem "creativity", even though human growth and development are parasitic upon these creative forces. He called upon conservation biologists, restorationists, environmental managers, philosophers, anthropologists, humanists, economists, and citizens to join in the search for appropriate public values to guide resource management.

Freemuth and Cawley (1993), political science professors, analyzed the pioneering attempt to implement ecosystem management in the Greater Yellowstone Area in the late 1980s. They cite the lack of a definition of ecosystem management as its major shortcoming. This resulted in a lack of trust by the public, even though resource managers were comfortable with the concept. A large part of the problem was that no definitive boundaries were drawn around places (Freemuth and Cawley 1993).

Management decisions define the character of local communities as much as they do land-use practices, and the needs and aspirations of local people have to be included in ecosystem management as do national interests (Freemuth and Cawley 1993). Caplan (1992), a Forest Service staff member, said, "A vision of 'ecosystem health' has little meaning unless it is married to particular resource management methods that will bring it about."

Ecosystem Components and Characteristics

To make any sense of ecosystem management, the first step is to define an ecosystem. That isn't easy. The dictionary (Random House 1971) says it is "a system formed by the interaction of a community of organisms with their environment". Forest scientists (Waring and Schlesinger 1985) have said that "a forested ecosystem includes the living organisms of the forest and extends from the top of the tree to the lowest soil layers affected by biotic processes."

Kimmins (1992) said that to understand many current forestry issues, one must understand what a forest ecosystem is, how it works, how it changes over time in the absence of disturbance, and how well it is able to recover after disturbance. Many people lack this understanding. Discussions of the ecological impact of forestry therefore are often based on emotional responses to images of recently disturbed forest ecosystems instead of scientific analysis of how ecosystems function in response to disturbance. A forest is more than just a stand of trees. It is a landscape that has the soil, climate, and set of biological organisms that make up what people think of as a forest. It is a type of landscape dominated by trees, that following the removal of trees by natural or human-caused disturbance will redevelop its plant, animal, and microbial communities either naturally or with human assistance. Following the death of trees in a forest, whether the cause is fire, wind, insects, disease, or human harvesting, the processes of ecosystem recovery and forest renewal begin. The forest ecosystem continues to exist despite the temporary removal of the large trees that dominated the landscape and thus defined the forest. Only the condition, state, or seral stage of the forest has changed. In some parts of the U.S., many farms are really forests that have been held back from natural ecosystem development processes by massive inputs of human and fossil fuel energy. Remove those inputs and the trees begin to recolonize the site (Kimmins 1992).

A forest ecosystem, as described by Kimmins (1992), is the trees, other vegetation, animals, and microbes that make up the living or biotic components. It also includes non-living or abiotic components including climate, the physical components of soil, and the topography. A forest ecosystem is a total environment. It is much harder to destroy a total environment or ecosystem than it is to change its present condition. Discussions of the destruction of forest ecosystems are usually about changing the condition of those ecosystems. A preferred ecosystem condition may be lost or foregone by natural or human events, but the forest ecosystem is destroyed only if the processes of ecosystem recovery are prevented from operating. Complete ecosystem destruction occurs only with the most severe and extensive disturbances such as volcanic eruptions, large landslides, or the clearing of land for an industrial park or shopping center (Kimmins 1992). Basic ecosystems and their capabilities continue to exist even during periods when forest health is declining, much as an individual human is sick at different points in time but recovers to a healthy state (R. Everett, review comments).

Kimmins (1987) identified trees, fish, and terrestrial wildlife as the principal biotic products yielded by forest ecosystems. The basic resource from which these biotic components develop is the physical environment—the soil and local climate. Soil is generally a nonrenewable resource that must be conserved in order to maintain the renewability of the plant and animal components (Kimmins 1987).

The components of an ecosystem can be listed much in the same way as the parts of an automobile (Kimmins 1992). But one should avoid comparing an ecological system and the functions of its component parts to a machine (Botkin 1990). Kimmins (1992) said one reason for avoiding the machine analogy is that ecosystems possess characteristics that transcend the list of their physical and biological components. These are the properties of the ecological system rather than its collection of parts, and include such things as the structure, function, complexity, diversity, dynamics, and interdependency or interaction of component parts (Kimmins 1992).

One of the most important properties of ecosystems according to Kimmins (1992) is their dynamics, or tendency to change over time. In addition to periodic disturbances from many sources, ecosystems have processes that constantly change their conditions towards a relatively stable self-replacing condition called the climax stage. But even undisturbed climax forests may change over time. The complexity of ecosystems is such that it is not helpful to generalize about the ecological consequences of a particular type of disturbance in different types of forest, or about different ways of managing a particular type of forest ecosystem. Each type of ecosystem and each kind of disturbance has to be considered individually (Kimmins 1992).

What does Ecosystem Management Promise?

Ecosystem management promises that ecological and economic concerns can be dealt with in an integrated and coordinated fashion, rather than considered as mutually exclusive or opposing goals. This is to be accomplished by addressing social, economic, and ecological concerns together in the decision-making process. An expected benefit is resolving some problems related to the conservation of imperiled species and their habitats that arise under the single species approach currently used to implement the Endangered Species Act.

According to Agee and Johnson (1988), "ecosystem management is a way to produce desired conditions and preserve future options." During an ecosystem management workshop held in 1986, discussions identified several emerging principles or characteristics of ecosystem management. The need for cooperation among different agencies, and the need for clearly defined problems and high quality information was emphasized, even though decisions must be made with less than complete information. Multiple use was identified as a characteristic of ecosystem management (Agee and Johnson 1988):

> Over the long term, ecosystem management must accommodate multiple uses at a regional scale and dominant or restricted use at the unit or site scale.

Two key issues emerged from the 1986 workshop. One was the definitional problem of establishing common ground as to what an ecosystem is and what criteria can be selected to represent management success. This is actually a scale problem, because ecosystems are hierarchial, one nested inside another until the entire planet is considered an ecosystem. The other was the problem of measurement, and the associated problems of developing information bases and monitoring (Agee and Johnson 1988).

A central tenet of ecosystem management is adaptation to local ecological conditions (Swanson and Franklin 1992). Adaptive management, according to Walters (1986), also includes a time dimension, as ecosystem responses are monitored and actions adjusted accordingly. This adaptive and locally-focused approach to forest resource management may therefore be especially responsive to local social concerns (Brunson 1993). Freemuth (review comments), however, noted that problems may be expected if local social conditions do not favor ecosystem management. Until ecosystem management is better defined, he said it is likely to be viewed as an overly flexible approach that allows technical experts to manage local ecological and social conditions. Management by technical expertise is how Freemuth believes the USDA Forest Service lost the public's trust, and it is not likely ecosystem management will restore trust if people don't understand it. One of the key problems with implementing ecosystem management is how the concerns of local communities will be incorporated in discussions. A plan will not be socially acceptable unless it does (J. Freemuth, review comments).

Focus on social, economic, and ecological concerns. Ecosystem management may be thought of as the optimum integration of social values and expectations, ecological potentials, and economic as well as technological considerations (Everett et al. 1993). Shortly after he announced the ecosystem management policy in June 1992, Chief Dale Robertson was asked to look 10 years into the future and consider how the Forest Service and the National Forest System would be different as a result of ecosystem management (Sampson 1992c). He replied that it will "reposition" the Forest Service. In the future he hopes "to see a healthier forest, a more scenic forest, a more natural-looking forest with abundant fisheries and wildlife, and people proud to be a part owner of this land."

Ecosystem management should be a social process with continuing dialogue between resource managers and people concerned about the lands and resources being managed. New information should be considered jointly and planning efforts should be collaborative, leading to management decisions that should fully consider social values (Everett et al. 1993).

Johnson (1993) said the community level is where many social, economic, and ecological concerns can be dealt with most successfully. Forest management policies for federal, state, and even private lands in the Pacific Northwest focus increasingly on the long-term health of forest ecosystems. Timber harvesting will likely always remain important, but forward-thinking managers of public forest land are looking at other ways to tap the economic potential of the forests, including recreation, education, research, and restoration. They are seeking to reconcile economic development and environmental protection. The idea is not some mythical "balance" between them. The goal is to find synergies; ways that economic activity can promote a healthy environment, and that healthy ecosystems can enrich their inhabitants, including rural communities, economically and otherwise (Johnson 1993).

The dialogue for implementing ecosystem management is underway. Because it promises to manage federal lands differently, people in regions with extensive areas of federal forests nervously await the uncertain outcome. Because it promises a different approach to forest resource management on all ownerships, all forest landowners are anxious about the outcome.

Ecosystem management and biodiversity. Callicott (1992), a philosophy professor, hoped that concern about ecosystem health would bolster the cause of biological conservation. He said the benchmarks of conservation biology are "under withering attack by an insidious skepticism within the scientific community."

USDA Forest Service Deputy Chief James Overbay (1992) said that ecosystem management on the national forests has "a bias toward diversity." Many discussions of how national forests should be managed focus on biological diversity. This is partly because the National Forest Management Act of 1976 says the Forest Service is to provide a diversity of plant and animal communities, and partly because some species have become or currently face becoming extinct as human management of ecosystems.

Endangered species habitat conservation. Some discussion of ecosystem management occurred during President Clinton's historic Forest Conference in Portland, Oregon, in April 1993. According to Jim Geisinger, a spokesman for the forest products industry in the Pacific Northwest, ecosystem management is a way to break the timber gridlock in the region. The idea is to set in place a policy that moves beyond spotted owl conservation controversies by considering much broader ecological impacts on old-growth forests, water systems, soils, and other wildlife. Environmental groups reacted suspiciously to industry's embrace of ecosystem management. Part of the reason is that industry stipulated that ecosystem management be applied across a broader land area than just the fraction of national forests currently allocated for timber production today (Associated Press 1993a).

The U.S. Fish and Wildlife Service agreed, in December 1992, to review petitions for listing new endangered species through an ecosystem-wide approach. For example, in the Pacific Northwest the spotted owl, marbled murrelet, and several salmon species have been and are being reviewed separately. If a similar situation were to arise in the future, all of them would be reviewed at one time. Frank Gladics, a forest industry association official in Washington, D.C., expects this agreement to put pressure on Congress to ease the economic impacts of the Endangered Species Act. Gladics said, "It probably will increase the number of species that are listed and for which recovery plans are written. That will heighten awareness among the American people of the devastating impacts of the law and they will support more reform in the law, rather than less" (*Public Lands News* 1993a).

Bruce Babbitt, Secretary of the Department of the Interior, said "Everyone agrees we're going to need to revisit the concepts of the Endangered Species Act" and determine if we can't find some way to look at ecosystems on a multi-species basis and ask how it is we can take reasonable steps to "deal with the economic tradeoffs" before a crisis erupts. The idea is that both conservation and business interests can be better served by negotiated settlements that plan the future of an entire ecosystem before any individual species are endangered (Stevens 1993).

Ecosystem Management and the USDA Forest Service

Forestry appears to be undergoing revolutionary change, brought about over a period of decades by new scientific findings, and spurred on by environmental concerns of the public (Brooks and Grant 1992). People are expressing concern about the characteristics of the forest—biodiversity, old-growth, endangered species, long-term productivity, and sustainability—much differently than the traditional short-term focus on outputs. This has caused the USDA Forest Service to examine its operations from a new perspective (Quigley 1992a). The New Perspectives program of the Forest Service has now evolved into "ecosystem management" (Salwasser 1992).

In a June 4, 1992, letter to Forest Supervisors and Research Station Directors on Ecosystem Management of the National

Forests and Grasslands, Chief Robertson (1992, see also Gray 1992a) explained the evolution of New Perspectives into Ecosystem Management. He said forest health will play a role in the new Forest Service focus (emphasis added):

> By ecosystem management, we mean that an ecological approach will be used to achieve the multiple-use management of the National Forests and Grasslands. It means that we must blend the needs of people and environmental values in such a way that the National Forests and Grasslands represent diverse, healthy, productive, and sustainable ecosystems.

According to Jerry Sesco (1992), Deputy Chief for Research, one of three future directions for Forest Service research is "understanding ecosystems." He said this will provide the scientific basis for addressing "health and productivity issues."

The six principles of ecosystem management, as laid out by Deputy Chief James Overbay (1992) and refined by social scientist Tom Quigley and ecologist Steve McDonald (1993) are as follows:

[1] **Sustainability.** Restore and maintain diversity, health, and productivity of forests and grasslands. Provide commodities and uses consistent with sustained vitality and resilience of ecological systems.

[2] **Dynamics, Complexity, and Options.** Ecological systems have a characteristic range of natural variability. Change is fundamental. Scale is important and predicting outcomes is complex and uncertain. Conservative approaches and adaptive management are key to maintaining options and addressing risk for the future.

[3] **Desired Future Condition.** Integrate ecological, economic, and social considerations into practical, clearly stated, measurable objectives. The desired future condition may change through time, reflecting dynamic ecological systems and public values.

[4] **Coordination.** Ecosystems ignore administrative, ownership, and jurisdictional boundaries. Cooperation with others and coordination of goals, plans and analyses is essential, especially at larger scales.

[5] **Integrated Data and Tools.** Inventories, classifications, mapping efforts, data bases, and analysis methods that cut across traditional functional disciplines are necessary.

[6] **Integrated Monitoring and Research.** Research and monitoring must be more fully integrated with management in providing a strong scientific basis for management decisions.

In the fall of 1993, more than a year after the Chief announced the policy, no one in the Forest Service can define the term ecosystem management. During an interview (Hopps 1993), Jim Lyons was asked how the Forest Service is setting ecosystem management in motion. He replied, "We're still defining what ecosystem management consists of. But most importantly, the Pacific Northwest is serving as a laboratory to see how ecosystem management might be implemented."

What is Ecosystem Management?

"The meanings of the concepts ecosystem and ecosystem management suffer from the same semantic difficulties as diversity, carrying capacity, stability, and other resource-related terms: they mean different things to different people" (Johnson and Agee 1988). This section does not offer a definition of ecosystem management but reviews what the concept means and how it has been applied.

The Forest Service (Leonard 1993) defined the term ecosystem management as an ecological approach to multiple use management of the national forests that blends the needs of people and environmental values in such a way that the national forests represent diverse, healthy, productive, and sustainable ecosystems. An ecological definition of forest health would include plant and animal communities and the cycling of nutrients and water within and between its living and non-living compartments that maintains an equilibrium between growth and mortality. Reproduction of the plant and animal systems would be sustainable (Leonard 1993). Blending the needs of people with environmental values remains the greatest challenge.

Although it has been around for more than 20 years (see Caldwell 1970), the concept of ecosystem-based management is still in its formative stages. Keiter (1990) said ecosystem management takes a regional perspective and regards natural boundaries such as watersheds or wildlife habitats as the appropriate focus for management decision making, thus transcending traditional jurisdictional boundaries. He identified four evident characteristics of ecosystem management. [1] interagency cooperation, [2] analysis of the full geographic and cumulative impacts of land management practices on resource systems and ecosystem processes, [3] a close linkage to modern conservation biology and its commitment to preserving biological diversity, and [4] in national parks and wilderness areas, a commitment to retain and preserve the natural integrity and appearance of an area in light of aesthetic and amenity values (Keiter 1990).

Based on Freemuth and Cawley's (1993) observations about ecosystem management in the Greater Yellowstone Area, there are two competing ways to view the concept. Ecosystem management for many professional resource managers is the application of sound scientific principles to resource management questions. As such, its legitimacy has been established, and it is neither an opinion nor a preference. The second view is more problematic, and is an opinion or preference. The words ecology and ecosystem are, according to Freemuth and Cawley, "political code words guaranteed to meet opposition from commodity user groups." They pointed out that these two words are used in the policy dialogue to draw boundaries. Thus ecology is symbolized as an opposing alternative to traditional resource management practices. Ecosystem management, viewed in this light, is a preference or opinion that has not been made legitimate through public deliberation (Freemuth and Cawley 1993). This is unfortunate, because the choice of a different term such as landscape-level management may have diffused some of this opposition.

A key problem with ecosystem management will be obtaining legitimacy from the public. That will mean [1] drawing ecosystem boundaries and explaining to the public how established place meanings will be affected, and [2] clarifying the linkage between science and public discourse, and the role of professional resource managers (Freemuth and Cawley 1993). Discussions among resource professionals regarding ecosystem management are underway.

A task force report to the Society of American Foresters (Norris et al. 1993) used ecosystem management to mean an ecological approach to forest resources management that attempts to maintain ecosystem processes and keep them functioning well over long periods of time, in order to provide "resilience to short-term stress and adaptation to long-term change." The condition of the forest landscape is the dominant focus of ecosystem management, and the sustained yield of products and services is provided within this context. Humans are part of the ecosystem, so products and intensive resource management may be part of the ecosystem management mix. In short, ecosystem management is a strategy by which the full array of forest values and functions is maintained at a landscape level, and relies on coordinated management across ownerships as an essential component (Norris et al. 1993).

On September 7, 1993, the federal government with much fanfare released what is known as the Gore report. It is a plan to "reinvent government" that reaches into every nook and cranny. One recommendation of the report was to "rationalize federal land ownerships." The report says adjoining land is often managed by several agencies and that federal lands should be run based on "ecosystem management." The Gore report did not define the term nor describe how this might be accomplished (*Public Lands News* 1993b).

In September 1993, the following definition was heralded as "the clearest definition yet" by one correspondent on the Forest Service's computer message network. It is interesting that the definition was not generated by the Forest Service, but by a citizen (Gorman 1993) imploring the agency to come up with precise terminology in an Op-Ed piece in *The Oregonian*:

> Ecosystem management is the human element of altering, by careful manipulation, the communities of all living organisms and all of the physical and biological factors that together make up their environment, within a previously specified boundary, which has as its goal a long-term sustainable balance that provides for the maximum benefit of all recently historical species (1800 A.D.) and environmental factors that influence those species, with preference given to none.

This definition is a good starting point, but ecosystem management may also include the cessation of altering the environment (M. Brunson, review comments).

Professor Mark Brunson, of the Department of Forest Resources at Utah State University, has been working on the social aspects of ecosystem management for several years (see Brunson 1993). His current thinking (M. Brunson, pers. comm.) on the meaning of ecosystem management is:

> *Ecosystem management* is a philosophy of forest stewardship in which proposed actions are evaluated on their ability to meet three criteria: [1] practices and conditions must be ecologically sustainable, directing managed forests toward a "desired future condition" that embodies the complexity of ecosystem interrelationships at a variety of spatial and temporal scales; [2] they must be economically feasible, meeting society's demands for the myriad products of forests at a cost which does not exceed the benefits achieved; and [3] they must be socially acceptable, reflecting a sensitivity toward recreational, aesthetic, and spiritual values of forests. An ecosystem management "tool kit" contains ecologically-based innovations refined through adaptive management, as well as time-tested techniques such as those for high-yield timber production.

The ideas and terms in the above definition are not new, but the way they are organized is. The three criteria of ecological sustainability, economic feasibility, and social acceptability would be used to evaluate proposed management activities. Ecological sustainability is conceptually the most difficult of the three criteria. The use of "desired future condition" makes the idea goal-oriented, which is a prerequisite for adaptive management. Can a definition of ecosystem management be anything less than this? It should probably be more. These three criteria are part of the set of five criteria that Clawson (1975) proposed for evaluating any forest policy. The other two were economic equity—who gets the benefits and who pays the costs—and administrative practicality. Ecosystem management needs to be considered in light of these criteria, too.

Brunson's definition adds only one new word to Clawson's set of five criteria. Clawson used "physical and biological feasibility" rather than "ecological sustainability." One could argue that these two phrases are either similar or dissimilar, depending upon how sustainability is defined. Gale and Cordray (1991) provided eight definitions of sustainability in a forestry context, ranging on a continuum of management intensity. The sustainable possibilities are [1] dominant product, [2] community, [3] human benefit, [4] "global village" (sustain ecosystems and human benefits), [5] self-sufficient ecosystem, [6] ecosystem type, [7] ecosystem insurance, and [8] ecosystem-centered sustainability.

As a policy for guiding decisions about natural resources, ecosystem management can be distilled down to three essential characteristics. These can be understood best by considering how ecosystem management will be different than the current or traditional approach to natural resource management. First, ecosystem management will mean a change from sustained-yield resources management to sustainable management. Second, the focus of this new management philosophy will be on what remains in the forest ecosystem after management activities, rather than on what goods and services are produced by those activities. Depending on the ecosystem, this will likely mean less of some products—for example, timber, water quality, and deer—and more of others—scenic beauty, water quantity, and some species of birds. Third, the larger spatial scale of ecosystem management at the landscape level involves crossing political and administrative ownership boundaries to plan resource management activities. The needs of different ownerships are reflected by different management objectives for particular land areas. Dealing with these spatial constraints is a major change from current public resource management planning, and may mean that private land management activities and outputs will constrain public land managers.

Table 10-1 is a comparison of the traditional sustained yield resource management approach and the ecosystem management approach. It is evident that ecosystem management is a broader concept.

In relation to diversity, Kimmins (1992) said that ecosystem function in any given seral state may be less dependent on the maintenance of a high level of biodiversity than is sometimes suggested. The available scientific evidence does not support the idea that the loss of a single species of bird or small mammal will result in a dramatic alteration of a forest ecosystem. (There may be important "keystone" species, however, that play key roles in certain ecosystems.) Furthermore, the

Table 10-1. A simplified comparison of traditional sustained yield and ecosystem management strategies, from a resource management point of view.

	Traditional Sustained-yield Management	**Ecosystem Management**
Objective	Sustained flow of products to meet human needs	Sustained flow of products to meet human needs
Constraints	Minimize adverse environmental effects and economic costs	Maintain ecological and desired forest condition
Strategic model	Resembles the agricultural model	Reflects patterns of natural disturbance
Characteristic emphasis or focus	Production efficiency and quantity of products	Biological complexity and condition of forest
Unit of management	Stands and aggregations of stands within one ownership	Landscapes and aggregations of landscapes across ownerships
Rotation time period	Determined by landowner objectives	Reflecting natural disturbance (intensive management will cause shorter length)
Current status	In transition, new knowledge and new values are being incorporated	Evolving
Future application	Remains valid for portions of landscape	Accepted on USDA Forest Service and USDI Bureau of Land Management lands

Source: Adapted from Norris et al. (1993).

maintenance of a given pattern of diversity requires management, because without it, natural processes will produce a continually changing mosaic of biodiversity in forested landscapes. Nonetheless, Kimmins said (as did Aldo Leopold 1949a) that we should probably try to keep all the parts as we tinker with forest ecosystems, and maintain species and their ranges wherever possible. Ecosystems will not fail to function if every species is not present in every ecosystem all the time. A broad landscape view of ecosystems and biodiversity makes more sense than a narrow local view (Kimmins 1992).

Implementing Ecosystem Management

Whatever ecosystem management is and whatever it may become, it is likely that two approaches will be used to apply the concept to resource management. Landscape management (or landscape ecology) will be used to coordinate resource management across larger-than-traditional scales of time and space. Restoration ecology will be used to achieve desired future conditions on portions of the landscape that have been degraded to the point where they are no longer in a "healthy" condition.

To understand how ecosystem management might be implemented, it is necessary to have some appreciation for landscape ecology, the theory behind landscape management. Restoration ecology is also a part of ecosystem management that can be used where natural or human-caused disturbances have altered the landscape. And because ecosystem management will attempt to achieve results in the future based partly on benchmarks from the past, the concepts of historic range of variability and desired future forest conditions have emerged as key features of ecosystem management. Each of these topics is reviewed in this last section of the chapter.

Landscape ecology and management. Ecosystem management, if nothing else, is an approach to integrated resource management. The following quotes from Forest Service officials and the Society of American Foresters task force illustrate the need for an integrated approach at a landscape scale:

> As ecosystem management principles are shaped into day-to-day practices, the approach demands the full integration of disciplines and methods as the Forest Service thinks about, discusses, and manages resources (Caplan 1992).
>
> The Forest Service approach to resource management is evolving from a focus on stand or site level resource management to managing toward desired outcomes that balance human needs within sustainable ecological systems at the landscape scale (USDA Forest Service 1993b).
>
> The Forest Service will make mistakes while the agency is learning and developing the ecosystem management concept. It is a philosophy, a way of thinking and acting that will take time and courage to develop. But it is the road the agency must take in managing natural resources (Leonard 1993).
>
> Ecosystem management is achieved when all forest resource values are maintained in aggregate at the landscape level over time (Norris et al. 1993).

Landscape ecology.—Barrett and Bohlen (1991) said landscape ecology integrates ecological theory with practical application. Landscape ecology attempts to meet the need for more long-term, cost-effective, ecological research at the ecosystem and landscape levels by providing a hierarchial perspective. The hope is to provide insights into the management of landscapes "damaged" by natural and human-caused disturbances. Sustainability is a concern of this emerging field of applied ecology (Barrett and Bohlen 1991). Landscape ecology provides a foundation for experiments in maintaining healthy ecosystems through sustainable ecosystem management, while accommodating human population growth and associated resource demand (Everett et al. 1993).

The practical aspect of landscape ecology, according to Barrett and Bohlen (1991) is that natural resource management and research is enhanced by understanding ecosystem and landscape contents, thus helping lead the manager or researcher to the most appropriate approach. This understanding must include an integrated view of landscape theory, hierarchial approaches, historical and predicted disturbance regimes, resources to be conserved, and socioeconomic constraints. Landscape ecology is a holistic approach rather than a reductionist view based only on site-specific concerns (Barrett and Bohlen 1991).

Landscape ecology is spatially oriented, and considers the relationship of adjacent units of land. For example, instead of treating each stand of trees in isolation, as the current planning model for national forests does, the relationship of one stand to another in a mosaic pattern is considered. Thus the landscape view is larger than traditional site-specific forest stand management.

Landscape ecology offers the potential to conserve biodiversity and long-term site productivity if existing landscape patterns and disturbance regimes closely follow effects or processes similar to historical conditions (Everett et al. 1993). Additional discussion of this point is provided in the ***Historic Range of Variability*** sub-section in this chapter.

According to Skok et al. (1992), the classification of ecological units for policy and management purposes is a fundamental challenge for researchers and managers. Implementing the concepts of ecosystem management needs careful attention and cooperation. Outcomes need to be monitored at a landscape scale to achieve effective policies, and management applications at the landscape scale have yet to be demonstrated, especially across mixed ownerships (Skok et al. 1992).

An inventory and classification of landscape structure and composition is a prerequisite to management prescriptions. In the context of sustainable ecosystem management, ecological landscape mapping units allow landscapes to be classified into easily recognizable units with similar topography, soils, potential vegetation, and response to disturbance. These mapping units are logical planning units useful for describing current and potential land characteristics (Everett et al. 1993).

Landscape management.—Landscape management is based on landscape ecology. It also integrates all other forest management topics. Kimmins (1987) argued that a solid foundation in ecology of the forest ecosystem is necessary for a well-rounded professional education in what he called the field of *total landscape management.* The traditional subjects of timber management and forest protection also need to be integrated with management of soil, water, fish, habitat, wildlife, range and recreation.

Oliver (1992) said the solution for environmental concerns associated with silviculture lies at the landscape level. It is here where the balance of stands of diverse structures and patterns can maintain habitats for a diversity of plants and animals (see Oliver et al. 1994). The Washington Forest Protection Association (1993) concluded that in a number of circumstances landscape management may offer a more effective and balanced approach to protecting wildlife in managed forests than the current species-by-species approach. Landscape management, when applied to wildlife resources, combines the principal components of landscape ecology and biological diversity. A landscape is a diverse land area of biological communities and physical features interacting with one another. Landscape ecology focuses on the structure, function, and change characteristics of the landscape. These landscape characteristics may be illustrated by habitat needs of resident wildlife. For example, pileated woodpeckers use large conifer snags, a structural feature of a forested landscape. These snags function as nesting and roosting trees until they fall, when they become foraging sites until they decompose. Over time, habitat within a landscape unit will change as fire, disease, and insects create large snags (Washington Forest Protection Association 1993).

Pilot projects in the Blue Mountains and in western Montana demonstrate that the principles of landscape ecology can be incorporated into land management planning and project design (Everett et al. 1993). An example of how this is done is provided in the following section.

Restoration ecology. The idea of health, ranging across a spectrum of conditions from being well to being dead, is applied to communities and ecosystems by nonscientists and scientists. The new field of restoration ecology often uses health terminology, because the concept of restoration is itself based on the idea of health (Rapport 1992b). For example, in the introduction to *Environmental Restoration*, Berger (1990) said:

> In the Northeast, thousands of lakes are dead or near death, and forests, too, are sick and dying from acid rain and other pollution. For the first time in human history, masses of people now realize not only that we must stop abusing the earth, but that we also must restore it to ecological health.

The Ecological Society of America has developed a proposal concerning "sustainable ecological systems." The theme of this proposal is to address the definition and detection of stress in natural and managed ecosystems, the restoration of such systems, and various management issues (Rapport 1992b). Lubchenco et al. (1991) suggested the need for new research initiatives to focus on the dynamics and sustainability of large ecosystems under multiple stressors. Holistic concepts of ecosystem health come into play here. Advances in clinical ecology will not only enable more rapid and accurate diagnosis of ecosystem pathologies, but also point to more efficient ways of restoring damaged ecosystems (Rapport 1992b).

Ecosystem degradation and restoration are related to health concepts. The conceptual foundation for defining health from a systems perspective must be integrated with social values in order to arrive at scientifically valid but necessarily subjective criteria for ecosystem health. Empirical work has already established some of the basic symptoms of many types of stressed ecosystems. As clinical ecology matures, the emphasis should shift away from curative approaches—those that focus on ecosystem disabilities—to preventive approaches—those that focus on ecosystem capabilities. The shift from curative to preventive medicine suggests the need to administer carefully controlled stress tests to ascertain the degree of ecosystem integrity. Stress tests may provide a method for discovering dysfunctional ecosystems well before any obvious problems appear. There are many problems with this suggested approach, including how to design non-invasive stress tests for critical ecosystem functions. Also needed is a better taxonomy of ailments, more rigorous diagnostic capabilities, and methods to validate proposed treatments or interventions in efforts to restore ecosystem health (Rapport 1992b). Some ecologists don't think these stress tests and diagnostic measures can be developed (see Kolasa and Pickett 1992).

Ecosystem restoration requires resources, including people, to get the work done. President Clinton's Forest Conference, held in April 1993 in Portland, Oregon, focused some attention on the employment aspects of ecosystem restoration, and the idea is gaining momentum as a means of addressing forest and watershed problems in the Pacific Northwest (Gray 1993a).

Reliance on pre-Euro-American settlement conditions for determining the success of a restoration effort limits the application of restoration techniques. There are also a number of problems that would need to be overcome including: [1] lack of information on pre-settlement conditions, [2] the presence of exotic species, [3] the possibility that pre-settlement conditions would not have persisted on their own, [4] questions as to the direction that natural change would have taken, and [5] the probability that modifications associated with settlement permanently made the area unsuitable for previous conditions. Some degree of "seminaturalness" is preferable because views of naturalness often ignore problems of scale. For example, the restoration of predators to some national parks may be desirable, but the parks are often isolated and too small to support a viable predator population. Attachment to natural conditions as a model for restoration may overlook some opportunities and inadequately address ecosystem change (Bratton 1992).

Restoring Ecosystems in the Blue Mountains.—Based on work begun by the Blue Mountains Natural Resources Institute (Quigley 1992a, and Wickman 1992, Mutch et al. 1993) the USDA Forest Service has developed a plan for restoring ecosystems in the Blue Mountains (Caraher et al. 1992). The Blue Mountains restoration plan uses an ecosystem approach, and takes three steps: [1] identification of river basins as the units of analysis (there are 19), and selected ecosystem elements as forest health indicators (there are 9), and estimating the "range of natural variability" for each indicator; [2] estimation of current conditions for each element in each river basin; and [3] inclusion of the concerns of stakeholders (there were 31) regarding ecosystem health and resource values at risk. These steps were used to identify river basins that were "far outside" or "within" their ranges of variability, and to identify long-term objectives for restoring forest health in the Blue Mountains.

In the Blue Mountains, the Forest Service intends to do this by attempting to attain the following key objectives (Caraher et al. 1992, summarized by Clark 1993b):

- reduce fire risk by reducing fuel buildup,
- reduce insect activity by improving the health of dense, weak, groups of trees,
- accelerate restoration of streams and riparian areas,
- restore healthy trees and vegetation to damaged areas,
- provide job opportunities in the private sector.

The Sustainable Ecological System strategy of the Forest Service's Region 1 has been adapted by Region 6 for restoring ecosystems in the Blue Mountains (Caraher et al. 1992). Gray and Clark (1992) explained how this was done, and provided an example from one of the 19 river basins that were profiled according to nine selected geological elements or indicators. A similar example is provided in Figure 10-1.

The key to the assessment of ecological condition presented in Figure 10-1 is determining the range of natural variability. USDA Forest Service scientists estimated these ranges by examining records of the ecosystems and landscapes prior to extensive timber harvesting and fire suppression activities. This process of historical characterization ranged from the mid-1800s to the mid-1900s. Then they estimated the current condition of each of the nine ecosystem elements and compared it to the range of natural variability (Gray and Clark 1992) as demonstrated in Figure 10-1. Five of the 19 river basins fell "far outside," five were "outside", and nine were "close to or within" what was called "a naturally sustainable range of ecosystem health" (Caraher et al. 1992). The Lower Grande Ronde, illustrated in Figure 10-1, was identified as "outside" that range.

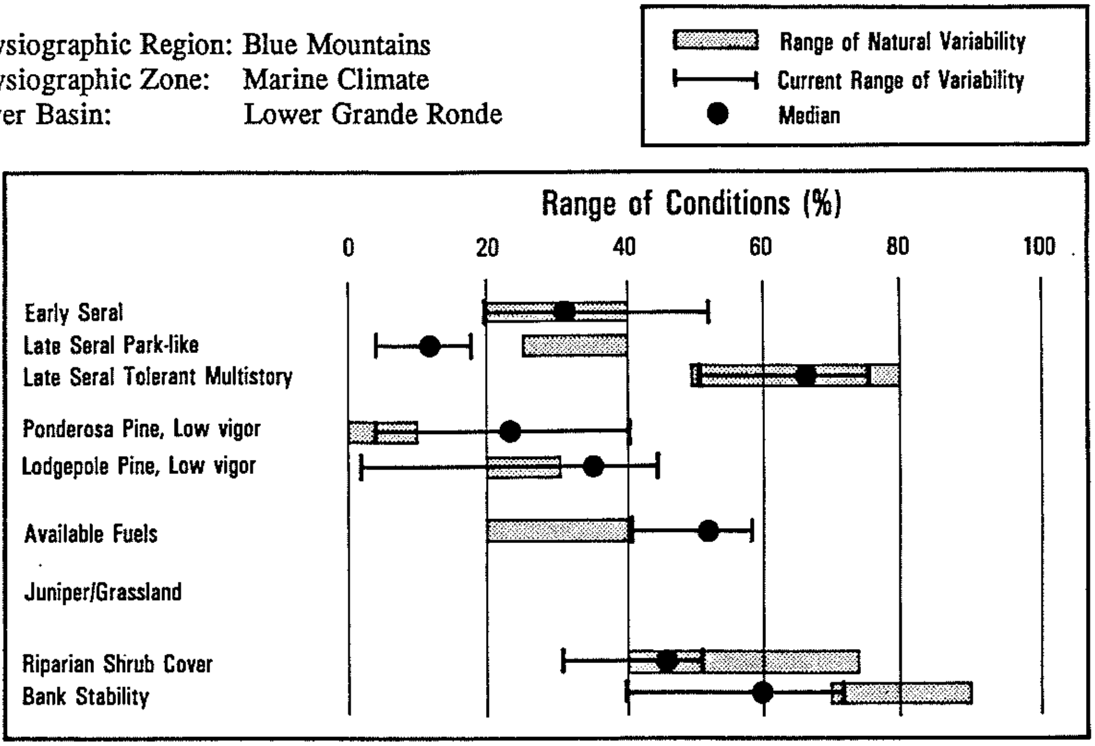
A panel of 31 people with a special interest or stake in the health of Blue Mountains forests was interviewed to determine which ecosystem elements best represented their concerns for ecosystem health and the resource values at risk (Caraher et al. 1992). The nine elements reflect their choices of ecosystem indicators. Their concerns for resource values at risk varied across the 19 river basins; those for the Lower Grande Ronde are displayed at the bottom of Figure 10-1.

Historic range of variability. What conditions should an ecosystem be restored to? When is an ecosystem unhealthy and in need of restoration? These are crucial ecosystem management questions. The reply heard most often to these two questions is the same: historic range of variability. The sustainable states other than historical conditions may be possible, and may be preferred to historical conditions, but we are uncertain if other states are sustainable with no loss in future biological or social options (R. Everett, review comments).

In order to accurately describe historical conditions and disturbance events that created them, researchers need to sample at several points in time and at different spatial scales. The description of historical conditions is not a single snapshot in time, but an array of landscape conditions that will promote achievement of management goals, including sustainability (R. Everett, review comments).

Lower Grande Ronde River

Physiographic Region: Blue Mountains
Physiographic Zone: Marine Climate
River Basin: Lower Grande Ronde



Lower Grande Ronde River Basin

Wallowa Whitman National Forest
- Riparian zones at risk to Douglas-fir bark beetles
- Old growth stands at risk to Douglas-fir bark beetles
- Really high road density
- Past partial cutting has drastically reduced the mature ponderosa pine/western larch component in the late seral communities leaving pure stands of manageable Douglas-fir/grand fir at high risk to forest pests. Game cover and peak flow standards and guidelines in forest plan restrict silviculture treatments in this forest type

Umatilla National Forest
- Loss of big game habitat from logging and defoliation
- High potential fire from defoliation (standing trees)

Stakeholders
- The higher elevations adjacent to the Wenaha/Tucannon Wilderness should not be logged.
- Concern for overstocking, excessive fuels. Do something now.
- North half of the River Basin is the worst.

Figure 10-1. Lower Grande Ronde River basin profile and assessment of ecological condition.

Source: Caraher et al. (1992, Appendix C).

In addition, our ability to accurately estimatethe historic range of variability is unknown, and the appropriate scale for investigation has yet to be determined.

Everett et al. (1993) recognized the value of the historic range of variability concept as a reference point, but not necessarily as a goal for ecosystem management. They said that maintaining biological diversity and long-term site productivity that was apparent before European settlement may not be appropriate everywhere because of ecosystem alterations. For example, white pine blister rust, climate change, increasing human population, or lack of congruence with social values and expectations may preclude some options. The scale, intensity, and frequency of disturbances necessary to achieve socially desirable landscapes should be defined through adaptive management, where needed information is developed through management experiments in an iterative fashion. Adaptive management requires quantification of clearly articulated objectives, an understanding of system operation, monitoring to provide information for rapid feedback and evaluation, and clearly articulated objectives (Everett et al. 1993). The historic range of variability is simply a guide to get the adaptive management process started.

A basic concept of ecosystem management is to recognize the "normal" range of successional variation for each ecosystem and maintain stand conditions within that range (Steele 1993). The Forest Service's Northern Region—Region 1 including northern Idaho and Montana—is taking the lead in developing ecosystem management concepts. The key to implementing what Region 1 calls Sustaining Ecological Systems is to identify a pre-European settlement range of variability for a number of ecosystem elements (Clark 1993a).

Everett et al. (1993) pointed out that all land and water ecosystems vary across time and space, even without human influence. Knowledge of this variability is extremely useful for providing a baseline to determine whether the current condition of a landscape is sustainable, given historical patterns and processes. Indeed, an initial template for describing ecosystem sustainability is provided by descriptions of historical landscape disturbance, such as fire frequency, and patterns of ecosystem components such as vegetation composition and structure (Everett et al. 1993). The rationale is that ecosystems are dynamic, and species have adapted to change and recurrent disturbance. Thus, maintaining a similar range of conditions is likely to provide adequate habitat for these species in the future, and to serve as an effective "coarse filter" (see Chapter 13) for these species in the future (P. Morgan, review comments; see Morgan et al. 1994).

Wildfire and native pests have been significant factors in many ecosystems. Ecosystem management involves applying what is known of the historical roles of wildfire and native pests (USDA Forest Service 1993b). Everett et al. (1993) recognized that when an ecosystem is outside the historic range of variability it is likely to be unsustainable. According to Penny Morgan (review comments) such a situation requires inputs of fossil fuel energy in the form of pesticides, fertilizers, or fuel for vegetation manipulation, or other human efforts to resist natural forces of change to maintain that state. Returning such ecosystems to a sustainable condition means restoring historic ranges of variability in disturbance effects, biological diversity, and long-term productivity. It does not necessarily follow that these cultural inputs should cease in ecosystem restoration efforts.

Restoring disturbance effects means restoring not just the effects of pre-settlement fire regimes, but insect outbreaks, root disease, and dwarf mistletoe epidemics, grazing, and hydrologic regimes of high and low flows (Everett et al. 1993). This can be accomplished through management activities that might include, for instance, partial cutting with broadened burning to create desired stand and landscape patterns (P. Morgan, review comments).

Pre-settlement historic conditions are not necessarily a management goal, nor does the use of historic range of variability imply that only nature will manipulate ecosystems in the future. Proponents of the historic range of variability concept suggest that it is simply a guide for management decisions. Furthermore, it has value as a communications device and as a tool for understanding ecosystem dynamics and adaptations (P. Morgan, review comments).

If goals for ecosystem management do not come from the past, where do they come from? Somehow people have to decide what ecosystem conditions are desirable. That is where the concept of desired future forest condition fits in.

Desired future conditions. Implementing ecosystem management, and the challenge of integrating the interrelationships that the ecosystem approach dictates, will require organizing principles that go beyond traditional approaches. The first question that might be asked is, what is the desired future condition for this ecosystem? The interactions of nature and the public must both be considered when answering this essential question (Leonard 1993). Haack and Byler (1993) observed that managing a forest for some desired future condition requires predictions about the future, and therefore managers need to understand the functions of forest insects and pathogens because they can exert a strong influence on the future. Thus forest health is a key component of desired future conditions.

Desired future conditions are defined in terms of ecological conditions that meet human needs and values without compromising future options (Everett et al. 1993). Caplan (1992) said the concept of desired future condition has already proven useful to federal natural resource agencies in discussions that link the past, present, and future, and then combine conservation philosophy to management methods. However, the concept is still evolving, as is ecosystem management. Desired future conditions can become the basis for agencies and interested individuals to explore large-scale ecosystem planning, management, and cooperation (Caplan 1992).

Desired future conditions are, according to Caplan (1992), the way people can express, in an integrated fashion, their visionary and pragmatic ideas about the future of ecosystems. Those expressions include: [1] the potential for human use and experience, including resource consumption, and [2] the natural resource or ecological legacy and condition that will exist as a result of attaining mutually compatible resource objectives. Desired future conditions need not be overly complex or technical, but they must describe conditions that reflect people's concerns and uses for the land. They should be flexible over time, and subject to regular study, revision, and adaptation. They will provide focal points for public dialogue about resource objectives, uses, and conditions in a non-technical way. They will provide ways to create integrated analyses and management plans for resources across ownership boundaries (Caplan 1992).

In testimony before Congress, Leonard (1992) said that the desired future condition in the Blue Mountains is healthy, vigorous stands. Silvicultural methods, including prescribed fire, will be used to reduce stand density and reestablish disease, insect, and fire-resistant species—ponderosa pine and western larch (Leonard 1992). This focus on stands is business as usual, not ecosystem management. Deputy Chief Overbay (1992) has moved the concept of ecosystem management forward, and stated that it favors diversity. But these are words, not actions, and it will be actions that determine whether or not ecosystem management is different, or business as usual.

According to Brunson (review comments), early implementors of the concept of desired future conditions hesitated to incorporate human desires because lay people did not understand ecological systems. Those implementors were biologists and natural scientists who assumed that the desired conditions were the historic conditions. Somehow the values that people hold need to be part of desired future conditions. One possible way to do this is to present alternatives to the public with forecasts of tradeoffs (M. Brunson, review comments).

The Forest Service is understandably confused about where it is headed. One official writes despairingly that "national forest plans have frequently resulted in 'zoning' documents that fracture and compartmentalize ecosystems in ways that help create forest health problems" (Cornett 1993). Another official is hopeful that the term desired future condition "will change over time, perhaps to something like 'ecological zoning' or 'ecozoning'" (Caplan 1992). To zone or not to zone—is that the question? Probably so. It will be difficult to implement landscape management without describing and analyzing many different types of zones.

Zones require boundaries. Boundaries, in the context of ecosystem management require specific lines to be drawn on maps. The political reality, according to Freemuth and Cawley (1993), is that until ecosystem management boundaries are delineated, people are shut out of the management planning process and asked to accept whatever solution agency scientists want to impose on the area. They quote Stone (1988) on the importance of politics, boundaries, and people:

> Ideas are the very stuff of politics. People fight about ideas, fight for them, and fight against them.... Every idea about policy draws boundaries. It tells us what or who is included or excluded in a category. These boundaries are more than intellectual—they define people in and out of a conflict or place them on different sides.

Until resource management agencies define these boundaries, ecosystem management will remain disconnected from the natural resources and environment that people care about.

Step one in ecosystem management will therefore involve drawing lines on maps, based on resource characteristics. Step two will involve the public as collaborative participants in determining what conditions they would like within these boundaries, and what uses would be compatible with those conditions. These boundaries will probably be dynamic, with revisions made as social and ecological changes arise. Forest health, because it is a desirable forest condition, will play a role in ecosystem management. The key to step two is the development of desired future conditions.

If desired future conditions are flexible and adaptive, objectives for implementing adaptive management will be defined directions or trajectories toward a desired condition. Healthy and vigorous forest conditions can be translated to specific objectives. Monitoring will indicate when managers are moving toward or away from desired conditions, and adjustments or adaptations can be made. Flexibility is provided as trajectories are adjusted to conform to changing social desires and increased ecological knowledge. One way to go about this is a continual, open process where participants are presented with resource base capabilities and management alternatives and tradeoffs. This differs from the current process of a fixed product such as a forest plan that becomes outdated with changes in public expectations or unforseen events such as insect outbreaks or other disturbances (P. Morgan, M. Brunson, R. Everett; review comments).

Conclusions

The condition of the forest landscape is the dominant focus of ecosystem management, and the sustained yield of products and services is provided within this context (Norris et al. 1993). Forest health is the condition of forest ecosystems, and is thus a dominant focus of ecosystem management.

It will be important to define and demonstrate ecosystem management to the public for it to be accepted. Whether this is accomplished or not, forest health will remain a concern.

The first step in implementing ecosystem management will be to define and circumscribe the boundaries of the appropriate units of analysis. This is a fundamental challenge for researchers and managers. Once ecosystem units have been defined and delineated, monitoring programs will be necessary to see if progress toward desired management objectives and desired ecosystem conditions is being achieved. If not, management will need to adapt to new sets of conditions or changing objectives. The appropriateness of desired future conditions needs to be socially determined, which will require close and ongoing working relationships with the public.

Some people eagerly await the implementation of ecosystem management, others fear it because it sounds like something they don't like. However, the concept currently offers the promise of healthy and sustainable forest ecosystems, which is what everyone wants. It therefore behooves everyone to become involved in the public dialogue that will be needed to develop collaboratively shared visions of future forests—desired future conditions or desired forest conditions.

One question people might ask is, how will things be different in the future than in the past? That is answered in a general fashion in Table 10-1. The Forest Service has not yet addressed this issue. Specifics will need to be developed that address local ecological and social needs. Ecosystem management promises healthy and sustainable forests, but action on the ground will be necessary to implement such a promise over the long term.

Chapter 11. Assessing Hazards and Risks

To avoid the need to treat every patient for every disease, physicians use diagnostic tools to identify patients at risk or in need of particular treatments. From a practical standpoint, it is necessary to take a similar approach to ecosystem health management.

The assessment of ecological risk is an important part of ecosystem management. The purpose of risk assessment is to improve environmental analysis (Schaeffer and Cox 1992). Formal risk assessment documents the current situation, possible future states or outcomes, and expected values associated with alternative strategies to achieve desired future outcomes (Beuter 1991).

The U.S. Environmental Protection Agency plans to redirect its Ecological Risk Assessment Research Program ("Ecorisk") in response to the Clinton administration's emphasis on managing natural resources at the ecosystem level. The Ecorisk Program previously focused on developing toxicity-based methods for assessing the risks single chemicals posed to individual species. The redirected objective is to develop methods and models for evaluating the ecological risks of management activities at the watershed level (National Council of the Paper Industry on Air and Stream Improvement 1993a).

Ecological risk assessment is an expanding field of inquiry. Several books that we have not reviewed have been published recently, including *Ecological Risk Assessment* (Suter 1993), *Ecological Risk Estimation* (Bartell et al. 1992), *Performing Ecological Risk Assessments* (Calabrese and Baldwin 1993), and *Predicting Ecological Risk* (Cairns et al. 1993).

Risk assessments have been part of forest resource management for some time. Hazard or risk rating systems have been developed to guide strategies for protecting forest stands. Decision analysis techniques have been used to formally assess risks associated with alternative natural resource management strategies. Forest ecosystem health management heightens the need for more and better hazard and risk assessment tools. The remainder of this chapter will briefly review hazard rating systems in the inland West and applications of risk analysis in natural resource management.

Hazard Rating

Managing forest health problems in the short term requires good early detection and hazard rating systems for pest outbreaks (Wickman 1992). The judicious use of risk-rating systems that have already been developed for ponderosa pine along with sanitation-salvage techniques may be valuable for maintaining healthy conditions in old-growth ponderosa pine stands. Research in northern California over a 22-year period revealed that by cutting high-risk trees that made up about 15% of a stand, the remaining stand had lower tree mortality from bark beetles than did an uncut stand (Wickman and Eaton 1962).

Forest stand damage factors. A key question, posed by Byler and Zimmer-Grove (1991), is what factors put stands at risk of damage? The answers are known. There are many predisposing factors. Stewart et al. (1984) provided a listing of them in the *Forestry Handbook*:

[1] Low quality site (c,d, and e apply mainly to plantations).
  a. Excessive or poor drainage.
  b. Thin or compacted soil.
  c. Excessive exposure.
  d. Soil characterized by organic and/or nutrient deficiencies. (This condition is most common on old agricultural lands or areas where top soil has been removed, that is, road banks and mining reclamation areas.)
  e. Abnormal pH.

[2] Species or specific planting stock poorly adapted to site.

[3] Changes in habitat.
  a. Raising or lowering water table.
  b. Exposure to increased light or wind movement as from thinning, harvest cuts, or from cutting of an adjacent stand.

[4] Stagnation as a result of overstocking.

[5] Stand or tree reaching entomological or pathological rotation age.

[6] Weather influences.
  a. Prolonged drought.
  b. Excessive rains.
  c. Unseasonable frost.
  d. Winter injury, including
    ▸Drying of foliage as a result of drying winds while the ground is frozen. Symptoms often do not become evident until spring.
    ▸Unusual extreme cold temperature resulting in foliage damage or death of twigs or injury to bark tissues.
    ▸Glaze, "ice storm," or wet snow.
  e. Lightning.
  f. Hail.

[7] Human activities.
  a. Fire.
  b. Grazing of domestic animals.
  c. Air pollution.
  d. Leaching of sodium chloride or other salts applied to adjacent roadways.
  e. Careless use of herbicides.
  f. Changes in soil level by grading, for example, at construction sites.

[8] Damage by wildlife.
  a. Browsing.
  b. Girdling, rubbing, or other bark injury by animals.
  c. Feeding on buds.

Using different categories of hazard potential, ecological restoration efforts can be linked to alternate investment levels, as the USDA Forest Service did in the Eastside Forest Ecosystem Health Assessment (see Everett et al. 1993, p. 37). One prevalent hazard is when stand age reaches the point where it is subject to disturbance from insects or disease, as in [5] above.

An ounce of prevention is worth a pound of cure. The *Forestry Handbook* (Stewart et al. 1984) instructed that the best control measure for many forest insects, mites, and diseases is prevention. Foresters need to be knowledgeable about specific conditions that may be conducive to pest damage. An example would be weakened trees caused by overstocking. Early detection of these conditions allows the scheduling of silvicultural treatments and other preventative practices. These practices include:

[1] Encouraging a mixture of tree species. Avoid large acreages of monotypes or plantings from a narrow genetic base.

[2] Choosing species and seed sources adapted to existing conditions on the site. Recognize that repeated fires or erosion may have rendered a planting site unsuitable to the species that previously occupied the site.

[3] Protecting against uncontrolled fire. This does not preclude burning of logging slash under expert supervision or prescribed burning of woodlands under carefully defined conditions and clearly demonstrated needs.

[4] Avoiding soil compaction and trampling by controlling grazing.

[5] Intermediate cutting to prevent stagnation, improve stand composition by favoring less susceptible species, and sanitize the stand of diseased and injured trees.

[6] Harvesting overmature trees.

[7] Applying pesticides to high value trees to prevent attack.

[8] Manipulating biological control agents (parasites and predators) to prevent pest population buildups.

[9] In harvest cuts, leave trees for a seed source that show pest resistance.

A tenth category is the treatment of insect populations while in the initial stages of population buildup with chemical or biological pesticides (virus or bacteria) (L. Livingston, review comments).

Pest rating systems. Hazard rating systems have been developed for several of the important forest pests. The following review of the risk rating systems is helpful in understanding the conditions that lead to epidemics of major forest insect pests in the region.

Mountain pine beetle.—The mountain pine beetle has been referred to as "the most destructive bark beetle" (Wood 1963). Risk rating systems for this insect in lodgepole pine stands will be used as an example. As with other bark beetles, some mountain pine beetle activity is always present, and during endemic periods, only an occasional tree is infested by the beetle. Then within a period of 6 to 10 years, from 25 to 50 percent of the lodgepole pine, 4 inches or more in diameter at breast height, can be killed by a beetle epidemic (Amman 1978).

Various methods of classifying lodgepole pine stands according to their risk of generating or sustaining a large beetle population have been developed. Regional classifications are based on the influence of climate and weather on beetle population increases. Identification of historical infestations has been used to locate the range of probable infestations. Latitude and elevation have also been used to rate climate as favorable or unfavorable to the mountain pine beetle (Amman et al. 1977).

Several stand-level approaches have been developed to classify risk within the general range of the beetle and its host species. The most widely used system was developed by Amman et al. (1977) and modified recently by Shore and Safranyik (1992). The most common stand variables are average stand diameter, average stand age, stand density (a measure of competitive stress), composition or species diversity (a measure of host availability), and measures of tree vigor (Mahoney 1978). The management implications of a classification method based on stand density and composition are that managers can prioritize stands by outbreak potential, and reduce the potential of beetle-caused mortality in high risk stands by altering stand composition and stand density (Schenk et al. 1980). Implementing such a classification system at the landscape level would help managers identify stands at the highest risk. Attention could then be focused on reducing risk by managing the types and configurations of species to avoid conditions that foster extreme outbreaks.

Fischer and Bradley (1987) said care must be taken when using fire to prevent or minimize scorching the crowns of residual overstory trees. Heavy fuel accumulations or slash concentrated near the base of overstory trees may require scattering or other treatment to avoid lethal cambium heating. Excessive crown scorch, cambium damage, or both can result in loss of vigor, increased susceptibility to bark beetle attack, or tree mortality. For example, the relationships between crown defoliation and mortality caused by the western pine beetle in ponderosa pine have been generalized as follows (Stevens and Hall 1960):

Percentage defoliation	Percentage of trees killed by beetles
0-25	0-15
25-50	13-14
50-75	19-42
75-100	45-87

Prescribed burning of understory vegetation and dead surface fuels can be carried out without serious threat of subsequent damage by bark beetles provided the overstory trees are not severely scorched. If accidental scorching does occur and bark beetle activity is detected, prompt removal of the severely scorched trees will reduce the probability of subsequent damage to healthy green trees. If scorching occurs outside the active growth period, scorched trees may recover and regain lost vigor. This may take 3 years, but signs of recovery should be visible during the first growing season that follows scorching (Fischer and Bradley 1987).

Douglas-fir tussock moth.—The Douglas-fir tussock moth periodically causes serious timber mortality and growth loss in coniferous forests of the Western United States. The three principal host species are Douglas-fir, grand fir, and white fir (Stark 1978). The adult female of this defoliating insect is flightless. This suggests that outbreaks develop in relatively small areas and that site and stand conditions favorable to the moth should be identifiable (Stoszek and Mika 1978). In major outbreaks, defoliation has been variable, with stands suffering heavy defoliation close to stands with little or no detectable defoliation. This variation is another indication that the dynamics of the tussock moth population were apparently influenced by conditions peculiar to particular sites and stands. In northern Idaho, according to Livingston (review comments), outbreaks have occurred on a regular cycle and in the same general area.

The following conditions were shown to be related to tussock moth defoliation in northern Idaho (Stoszek and Mika 1978):

- Ridgetop locations suffered heavier defoliation
- Stands with deep volcanic ash soils suffered less defoliation
- Defoliation was higher on the less productive sites
- Defoliation increased with average age of host trees (stands less than 50 years old showed little defoliation regardless of other factors)
- Defoliation was greater in stands with more variable tree heights
- Defoliation increased as the ratio of density to site productivity increased
- Defoliation increased as the proportion of grand fir increased

These relationships can be combined into models for predicting defoliation. Research in Oregon, Washington, and California has defined comparable relationships that have been used to model risk of outbreak and defoliation.

Western spruce budworm.—For the western spruce budworm, not only are stand and site factors important, but the ability of budworms to move in and out of the stand affects adjacent stands (Wulf and Cates 1985). Proximity to an area with high budworm density may make a neighboring stand susceptible. Some homogeneity of budworm habitat is a prerequisite for a sustained outbreak, so diversity of cutting practices and the interspersion of nonhost forest types may be important considerations for reducing damage.

Warm dry sites at lower elevations and on south-facing slopes are most susceptible to defoliation, with the most shade-tolerant host species usually sustaining the greatest damage. Stand susceptibility and defoliation increase with the proportion of host trees. Stand density also influences the level of defoliation, with most damage occurring in closed stands. Declining tree vigor is related to budworm feeding on Douglas-fir (Wulf and Cates 1985) and grand fir (Parks 1993). Douglas-fir trees under moisture stress are more susceptible to damage. Also, more vigorous trees have a greater ability to produce new foliage and recuperate once defoliation subsides. Stand structure also plays an important role in susceptibility. In multi-storied stands, larvae will be dispersed from the upper canopy to overtopped trees; if no subordinate trees are present or if they are a nonhost species, the larvae will fall to the ground and perish (Wulf and Cates 1985).

Tree age is positively correlated with budworm survival and stand defoliation often increases with the size of host trees (Wulf and Cates 1985). Foliage biomass (food for larvae) and bark furrowing (overwintering habitat) are related to budworm populations and increasing competition, resulting in a decrease in tree vigor. All these factors combine to make mature stands more susceptible than younger stands.

These site and stand conditions have been the bases for at least five different methods for ranking stands according to their susceptibility to budworm (Carlson 1985). Methods include aerial surveys, a climatological regression model, and photo interpretation with regression modeling.

Ecological Risk Analysis

Risk assessments for mountain pine beetle in lodgepole pine have been conducted throughout northern Idaho and western Montana, in USDA Forest Service Region 1. Results of such work have been used in combination with a loss assessment model to prioritize management activities in lodgepole pine stands in about half of the 20 ranger districts on the national forests in the region with extensive lodgepole pine stands (L. Livingston, review comments; K. Gibson, pers. comm.).

Insect hazard assessment models may be an exception. Beuter (1991) said formal assessment of risk in forest resource management has rarely been done, and when it has, it is often ignored. Examples of other assessments include the application of quantitative models to choose strategies for wildfire prevention and control, and project level decisions in reforestation, vegetation control, and the location and design of forest roads. The reasons why risk analyses have been ignored include the lack of site-specific information and uncertainty whether obtaining it is worth the effort (Beuter 1991).

Ecological endpoints or indicators of health. The fledgling practice of ecological risk assessment may provide quantitative values and probability estimates for major environmental decisions in the future. Proponents of risk assessment want to determine a rough rank order for environmental threats as a scientific basis for the government's environmental priorities. The National Research Council and U.S. EPA are working separately to create guidelines for risk assessment (Nash 1991).

Risk assessment has its detractors, who say that it is a highly arcane, technically complex method that preempts public dialogue under the guise of technocratic certainty. The level of uncertainty in risk assessments, say critics, makes them useless. Defenders of risk assessment argue, however, that uncertainty is inescapable, regulatory decisions must be made anyway, and the uncertainties are factored in (Nash 1991).

Unlike the health-risk assessment model, an ecological risk assessment scheme must accommodate multiple species, and many levels of biological organization as well as multiple stressors. Only a limited number of ecosystem characteristics (sometimes called endpoints), can be studied as indicators of ecological health. Which endpoints should be selected, and on what basis? There is a bewildering choice, from individual cells up to whole ecosystems. The death of an organism might be used, or a decline in the food web that supports a species. Population fluctuations beyond set limits or the spatial extent of a certain habitat could also be indicators (Nash 1991). The selection of indicators is crucial in ecosystem health assessment, and the subject of Chapter 13.

Valuation Problems.—The morass of ecological endpoints is a symptom of the fact that the government has not decided, or perhaps acknowledged, the goal of its regulations. For now, regulations try to maintain the ecological status quo. Alternatively, ecosystems might be managed toward reestablishing their condition in the 1950s, the 1750s, or prehistory. A decision will yield a finite set of endpoints. Underlying the choice of endpoints is the vexing question of the valuation of natural resources (Nash 1991).

Many ecologists balk at placing an economic value on ecosystems, arguing that they have innate worth that cannot be measured. The idea of putting a value on changes in the environment and balancing those against cost is not something these ecologists are comfortable with. One reason is that economists are identified with commercialism, exploitation, and development. But economists who do their analysis correctly are not interested primarily in profits and losses, but in social values, which include nonconsumptive, intrinsic values that people enjoy from natural resources in their natural state (Nash 1991). Another reason may be that ecologists presume that ecosystems will never be valued as high as economic values and thus unable to compete as a benefit-cost valued alternative.

Economists continue to search for acceptable methods for assigning monetary values to intrinsic values. Traditionally, they have relied on the marketplace to reveal value. But market values do not include the byproducts of economic transitions, such as air pollution or the extinction of a rare species. Nash (1991) said economists and ecologists often sidestep valuation of natural resources when advising policy makers. If ecologists don't go along to some extent with the search for improved valuation methods, the ecosystems that they want to protect are not going to be protected (Nash 1991).

In spite of the problems of assessing the risks of managing ecological systems, there are compelling reasons for doing so. All are related to mitigating adverse effects of human activities on the environment. These can be illustrated by considering two cases in the literature: a new program for assessing ecological risk in Illinois, and the need for assessing the risk of losing endangered species.

State level analysis example. The development and use of ecosystem threshold criteria is an important part of ecological risk assessment that can be accomplished at the state level. For example, in 1992, the State of Illinois initiated the Critical Trends Assessment Program (CTAP) to determine the "state of the State's" ecosystems. The results will be used to establish long-term environmental strategies in Illinois. Initially CTAP will examine temporal and spatial patterns of change over several decades in "sources" of threats such as manufacturing and demographics and in "receptors" that are defined as critical processes of ecosystems. A dichotomous decision key will be developed to determine the acceptability of the risk posed by various sources to ecosystems, allowing more detailed examinations. The assessment of an adverse risk can only be made by determining if ecosystem stresses are below thresholds that affect critical ecosystem processes. The acceptability of the risk to an ecosystem, as in human risk assessment, must be judged in relation to appropriate threshold criteria for adverse effects (Schaeffer and Cox 1992).

Endangered species and national forests. The comprehensive planning process for guiding national forest management implicitly includes environmental risk assessment. That decision environment is characterized by multiple objectives, increasing resource scarcity, a multitude of interests and agendas, and a lack of patience. Increasing concerns about the sustainability of forest resources make the awareness of trade-offs and risks associated with forest resource management more important than ever. These concerns include nonmarketed resources such as wildlife habitat (Beuter 1991).

In the context of the old-growth forest/spotted owl issue, Beuter (1991) posed several questions, most of them directly related to forest ecosystem health issues:

> The issue is not simply how much old-growth protection is needed, but it also includes consideration of forest management alternatives, both inside and outside of old growth reserves. Should forest fires be controlled? Should salvage of dead timber be allowed? Should roads and trails be allowed in reserve areas? Could thinning and selective harvesting occur without significant threat to the owl? The easy answer is to avoid any chance of adversely affecting owls by not allowing forest management activities inside reserve areas, and even limiting them outside.

These issues, spurred by the Endangered Species Act (ESA), are relevant to other species as well. Grazing as well as forestry activities in the context of imperiled salmon conservation fit the situation described above. Because of that, forests in the Inland Northwest are subject to the same questions Beuter asked in the narrower context of owls and old growth. Forests in the Inland Northwest are dynamic, too, and regulations prohibiting management in old growth may put at risk not only imperiled species, but the ecosystems upon which they depend.

A key issue is that over time, old forests will be replaced by young forests as disturbance factors perform their function. Without management activity, there is considerable risk that old forests and the species that depend on them will not be self-perpetuating.

Social and community aspects of issues associated with the conservation of imperiled species and their ecosystems are an important consideration in ecosystem management. The notion of desired future forest condition coincides with Beuter's (1991) concern: "What is lacking is agreement on a desired future state for these communities." Risk analyses could include social impacts as well as ecological impacts, even though some people question the relevance of such analyses in the listing and recovery planning processes under the ESA (Beuter 1991).

Beuter (1991) said listing decisions under the ESA are statements of perceived risk to the survival of imperiled species under existing conditions, often created by human activities. It would seem desirable for a listing decision analysis to include an assessment of the risk to the species in relation to the expected value of mitigation alternatives using interdisciplinary approach rather than only the perspective of wildlife specialists. If inappropriate in the listing process, then it perhaps should be required as the first step in the recovery planning process (Beuter 1991).

Wildlife specialists in the Forest Service are beginning to use risk assessments to analyze the requirement for providing diversity of plant and animal communities. They have used such analyses to assess population viability. In both cases, conservation goals can be expressed as probabilities of persistence (a measure of stability) given existing knowledge and uncertainties (Marcot and Salwasser 1991).

Maguire (1986, 1991a) has applied decision analysis techniques to endangered species conservation problems. She said (Maguire 1991b) that combining decision analysis and alternative dispute resolution techniques offers the potential for better integration of public participation and technical analyses in national forest management. This approach fits nicely with the requirements of the National Forest Management Act and the National Environmental Policy Act.

Beuter (1991) concluded that comprehensive analysis to balance risks becomes increasingly important in natural resources management. Nowhere is this more evident, he said, than in attempting to seek a balance of risks between the requirements of the ESA and other legal mandates driving forest management on the national forests.

Conclusions

Assessment of ecological risk is an important part of ecosystem management. Like ecosystem management, ecological risk assessment is a new and developing field. The practice applied at the ecosystem level promises to reduce uncertainty, but the selection of ecosystem characteristics or endpoints offers a variety of bewildering choices. Valuation problems are also vexing, as many ecosystem values are not market based. The need for sustaining populations of imperiled species and the ecosystems they inhabit make ecological risk assessment an important field of endeavor, in spite of its inherent difficulties.

Much forestry research has been directed at reducing the impacts of insects and diseases by hazard assessment. Some research has been directed at factors that promote outbreaks of pests, the prevention of conditions favorable to extreme outbreaks is a goal of managing forests for long-term health and productivity. Factors that predispose forests to pest outbreaks include tree species composition poorly suited or adapted to a site, overstocking, and old age. All of these hazard factors can be reduced through management activities. Unless that is one, all ecological, economic, and social values associated with forests are at higher risk than need be.

Chapter 12. Forest Policy and Forest Health

Our society has difficult natural resource issues to face, including the appropriate mix of general forests and wilderness areas, the conservation of biodiversity, and amenity outputs. These issues are addressed through public policies. If there is a future problem with the availability of domestic timber or other nontimber outputs, it will largely be the outcome of political forces, rather than biological constraints. Because of environmental concerns, areas of productive forests have been withdrawn from the timber base, largely on federal lands. Public policies affect the willingness of private forest owners to plant and harvest timber. Endangered species conservation could result in additional withdrawals from the timber base. Reductions in domestic timber production will likely be offset by decreased exports and increased imports (Sedjo 1991).

Forestry is changing, as are the forests and other resources in forested ecosystems. The public has some say about how forestry is conducted, particularly on public lands. Public concerns have resulted in a shift in forestry values, from what Cornett (1993) called sustained yield to sustainability. This change is reflected in the USDA Forest Service ecosystem management philosophy and in the Society of American Foresters Task Force Report on Sustaining Long-Term Forest Health and Productivity (Norris et al. 1993).

Forest health is an important part of current forest policy debates. This chapter provides a brief overview of policies that involve forest health in a broad sense. More specific policies that define forest health were described in Part I, particularly in Chapter 5. Specific policies for forest health monitoring are described in the next chapter.

National Forest Management Act

The land management planning process required by The National Forest Management Act of 1976 (NFMA) is the mechanism for translating the policy and concepts of ecosystem management into action. Ecosystem management moves beyond the traditional planning emphasis on individual resources to the dynamic nature of landscape patterns and processes and full consideration of spatial and temporal relations (Everett et al. 1993).

To the extent that forest health is part of ecosystem management, NFMA becomes an important policy guiding forest health management. Cornett (1993) said there is a legal basis, if not a mandate, for ecosystem management. It represents a logical evolution of the philosophy and intent of the Multiple-Use Sustained-Yield Act and NFMA. Science has shown that managing to ensure ecosystem health is the key to sustaining the productivity of that system. To meet the intent of these policies, national forest management needs to maintain the vigor, diversity, and resiliency of forest and grassland ecosystems. The species viability regulations within the Endangered Species Act and NFMA describe an inherent basis for ecosystem management, even though the need for managing habitat complexes in the context of species management was not universally recognized until recently (Cornett 1993).

Sustaining the health and productivity of ecosystems will involve the interdisciplinary scientific and public participation requirements of NFMA and the National Environmental Policy Act (NEPA). Cornett (1993) said that with the vision of hindsight, an "interdisciplinary" planning process does not automatically translate to integrated land management; and "public participation" can range from relatively meaningless to a full partnership in the decision-making process. The social interactions that took place during the development of national forest plans were typically adversarial (Cornett 1993). Forest planning will therefore need to be more effective and collaborative if it is to deal with ecosystem health and management.

The concern for healthy and productive forests is not a new theme (Gast et al. 1991). The Organic Act of 1897 states that:

> No national forest shall be established, except to improve and protect the forest within the boundaries or for the purpose of securing

> favorable conditions of water flows, and to furnish a continuous supply of timber... and The Secretary of Agriculture shall make provisions for the protection against destruction by fire and depredations upon the public forests and national forests.

More recent Congressional concern for forest health and the recognition of biological diversity as a component of a healthy forest is expressed in NFMA (Gast et al. 1991). NFMA explains that "It is the policy of Congress that all forested lands in the National Forest System shall be maintained in appropriate forest cover with species of trees, degree of stocking, rate of growth, and conditions of stands designed to secure maximum benefits..." NFMA requires the Secretary of Agriculture to "...provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives."

NFMA sets size limits on timber harvest areas, but these limits are superseded by the provision that "...such limits shall not apply to the size of areas harvested as a result of natural catastrophic conditions such as fire, insect and disease attack, or windstorm". R. Everett (Review Comments) said this recognizes that disturbances arise from natural conditions, and legislation should not attempt to control the frequency or size of such natural disturbances. The size of disturbance effects will be defined either by historical patterns or desired conditions across the landscape, as defined by site capabilities and management objectives (R. Everett, review comments). NFMA further allows standards that require stands of trees to have reached their culmination of mean annual increment (or biological maturity) prior to harvest. This requirement "shall not preclude the Secretary from salvage or sanitation harvesting of timber stands which are substantially damaged by fire, windthrow or other catastrophe or which are in imminent danger from insect and disease attack." In addition, NFMA requires that land determined to be not suited for timber production can not be harvested during the 10 year period of the plan "except for salvage sales or sales necessitated to protect other multiple-use values" (Gast et al. 1991).

National Policy Initiatives

Forest health became an issue at the end of the 102nd Congress in late 1992. Attention focused on serious problems in the Rocky Mountain West resulting from six years of drought and six or seven decades of fire-suppression. Other regions of the country also have forest health problems. Some groups support restoring health through vegetation management, others believe that this approach is just another excuse to cut more timber (Lyons and Tuchmann 1993).

The forest health issue emerged on the congressional agenda through the efforts of American Forests, a citizen conservation group that has promoted forest conservation since 1875. Representative Larry LaRocco (D-ID) and others introduced a forest health bill that passed the House Agriculture committee (Gray and Clark 1992). Rep. LaRocco reintroduced the bill in the House at the beginning of the 103rd Congress in 1993. Another forest health bill was introduced in the Senate by Bob Packwood (R-OR) (Gray 1993b).

The action program that would be created by Rep. LaRocco's proposed legislation is a several-step process that would allow federal agencies to focus programs and funds on rescuing sick forests and restoring forest health. In the process, major amounts of dead, dying, and over-crowded trees will need to be removed, so there would be a significant impact on the forest products industry of the affected regions, and on jobs in those regions (Sampson 1992d).

These projects would not be timber sales, however, in the sense of removing most or all of the merchantable trees. Instead, they would focus on the quality of the remaining forest—trying to convert it to the species that can survive and succeed under climate stress. More often than not, in Idaho those adaptable species will be pines. Thinning will be done so that competition for moisture and nutrients will decrease stress on the remaining trees. In some places, prescribed burns may be used; in others, some form of integrated pest management. The idea in the legislation is to allow resource managers to make those decisions, depending on their judgment as to what is needed on the land (Sampson 1992d). Because vocal segments of the public distrust resource managers, this legislation will be difficult to pass.

Sampson (1992d) said the major problem in this kind of legislation comes in trying to expedite remedial actions without steamrolling public participation and due process. Some critics in the environmental community feel that the forest-health issue is simply a "Trojan Horse" being used to justify more clearcutting and road building in roadless forest areas. Rep. LaRocco's bill tries to avoid both, but getting the language worked out will be a challenge to lawmakers. The following sets forth the current outline of the bill (Sampson 1992d):

[1] Congress would declare a "Forest Health Emergency" covering the damaged and fire-threatened forests in the West—and elsewhere, if the situation expands.

[2] For those forests that receive this designation, a "Forest Health Improvement Program" will focus public and private resources on the rescue of sick forests. This long-term program would bring together all relevant authorities and available funds, to focus on treating forest health.

[3] Paying for this emergency program—always an issue in Congress today—should be possible with minimum impact on the federal treasury.

Sampson said, the bill "is a good start" but "what is really needed is an effective forest health *action* program." Such a program, he said, would have two key parts (Gray 1992c):

- The first part—most urgent for public safety—is to remove dead and dying trees. The salvage of these trees can help the forest become more fire resistant and, if done within a year or two after they die, can retain the quality and value of the trees for processing wood products.

- The second part is thinning stands that are notyet dying but soon will be if action is not taken. This is the long-term element—thinning and improving the forest to make it more resistant to both drought and other stresses into the next century. In many places, thinning can be combined with other treatments to begin converting forests back to species mixes and stocking levels better adapted to their given sites.

These policy proposals unfortunately overlook public participation. Sharing information and developing shared visions of the future are important components of a forest health strategy (see Chapter 16).

Other Policies

In 1990, Congress amended the Cooperative Forestry Assistance Act of 1978 to include language to strengthen forest health protection. The amended act provides for promotion of silvicultural techniques that protect and enhance all forests. It also provides for forest health monitoring (Leonard 1992).

Monitoring is an important part of forest health management, just as it is in human health, and is the subject of the next chapter.

Conclusions

Planning the use and management of national forests under NFMA is an interdisciplinary exercise which must include public participation. Neither of these requirements is easy to attain. NFMA includes many forest health concerns, including plant and animal diversity and maximum benefits for society. It sets limits for timber harvest, except for areas affected by "natural catastrophic conditions." NFMA cannot deal with all forest health situations, because neither forest planners, disciplinary specialists, nor the public can predict the future.

New legislation at the national level may be needed to deal effectively with some of the forest health situations that have arisen in the Inland West. Some national forests may need additional funding and flexibility to treat unhealthy conditions, but run the risk of further erosion of public trust unless the public is included in the decision process.

PART III. DETERMINING FOREST HEALTH CONDITIONS

Chapter 13. Measuring Forest Health

Can Forest Health Be Measured?

We will not know whether the health of forest ecosystems is improving, stable, or declining until we become serious about long-term forest health assessment (Smith 1990). The same holds true for watersheds (Karr 1992). But can we do the assessment? Scientists have yet to devise methods for measuring ecosystem health, and perhaps never will. Ecosystems do not die in the sense that an individual organism or a population does, rather ecosystem characteristics and properties change. Although objective indicators of forest ecosystem characteristics can be specified and measured, forest health is subjective as it is based on value judgements. Some problems associated with these value judgments can be overcome by selecting representative ecosystem parameters to measure.

The measurement of forest ecosystem health depends first on the selection of indicators. They are defined and described in this chapter. Measures of indicators can be used to develop baseline data for the ecosystem under consideration, allowing the use of such data to develop standards. Monitoring can then be employed to collect data on current conditions for comparison against the standard.

Based on Aldo Leopold's writings, Monnig and Byler (1992) said forest health is best measured by how patterns and rates of change compare to historic processes. Variables such as presence/absence, relative abundance, distribution, and patterns of change for selected indicators monitored with standard sampling procedures. This information, coupled with historical information from other sources, might be viewed as representing an expected range of variability. By comparing current data with the patterns established through time, it is possible to see if they are within or outside the historic range of variability. It then becomes possible to make judgments about the status of the health of the forests. These judgements are necessarily subjective, as each participant in the decision making process comes endowed with his or her own specific set of needs and objectives. For example, a site where trees are killed by root disease and replaced with shrub species is seen as unhealthy by those whose objective is wood fiber production or protection from wildfire, while it may be judged healthy by those interested in having cover and browse for deer, or in increasing biodiversity. Indicators of conditions, such as the presence/absence of root disease, can be measured and monitored, but the inherent subjectivity of judgments about health will remain until a representative set of indicators has been selected and standards established.

Federal Laws

The quest for healthy and sustainable forests will require numerous approximations and continuous monitoring efforts (Monnig and Byler (1992). Several federal laws require nationwide forest ecosystem health monitoring, and programs are now being designed and implemented to accomplish these mandates. The tasks are being undertaken jointly by the U.S. Environmental Protection Agency, with cooperation from the USDA Forest Service and state forestry agencies. Laws that affect the Forest Service are summarized by Burkman and Hertel (1992), as follows:

The Forest Ecosystem and Atmospheric Pollution Research Act of 1988 (P.L. 100-521) directs the Forest Service to "increase the frequency of forest inventories in matters that relate to atmospheric pollution and conduct such surveys as are necessary to monitor long-term trends in health and productivity of domestic forest ecosystems." One result of this act was the Global Change Research Program. Another was the Forest Service forest health strategy (USDA Forest Service 1988) outlining a way to enhance, maintain, and monitor forest health (Burkman and Hertel 1992). This act is particularly important because it authorizes a 10-year program of research and monitoring to better understand the relationships between forest health and air pollutants and recognizes the need for long-term monitoring (USDA Forest Service 1992a).

The Cooperative Forestry Assistance Act (P.L. 95-313) and the 1990 "Farm Bill" (P.L. 101-624) authorized the Forest Service to conduct surveys to detect and appraise man-made stresses affecting trees, to monitor all forests to determine detrimental or beneficial changes over time, and to annually report the monitoring results.The amendments to the former law are important because forest health monitoring is explicitly authorized. Section 5 of P.L. 95-313, "Insect and Disease Control," has been redesignated Section 8, Forest Health Protection. Section 8(b)(1) directs the Forest Service to do the following tasks (USDA Forest Service 1992a):

> Conduct surveys to detect and appraise insect infestations and disease conditions and man-made stresses affecting trees and establish a monitoring system throughout the forests of the United States to determine detrimental changes or improvement that occur over time, and report annually concerning such surveys and monitoring.

National Forest Health Monitoring Program

Forest health issues include the effects of management activities, deforestation, habitat loss, air pollution, global climate change, and damage from a variety of forest insect and disease problems. The USDA Forest Service, U.S. Environmental Protection Agency, and other federal and state agencies must evaluate and respond to these issues. Timely response requires credible information on forest conditions based on data that can be compiled, analyzed, and interpreted to evaluate forest health. The National Forest Health Monitoring Program integrates federal and state monitoring activities to provide this forest health information (Miller 1991, USDA Forest Service 1992a). The State of Idaho does limited annual monitoring of forest insect outbreaks, in cooperation with the Forest Service.

Congress has provided the Forest Service the authority, direction, and funding to establish a nationwide forest health monitoring program. Within the agency, three divisions—Forest Pest Management in State and Private Forestry, Research, and the National Forest System—are involved in developing and implementing the initial phases of forest health monitoring (USDA Forest Service 1992a).

The national monitoring program evaluates forest health with respect to naturally occurring factors such as fire, forest pests, forest succession, site, drought, and weather extremes, as well as unnatural biotic and abiotic factors such as introduced pests, air pollution, and global climate changes. According to Forest Pest Management, and presumably the rest of the Forest Service, the term forest health denotes forest ecosystem resilience and productivity relative to a specified set of values, needs, and expectations (USDA Forest Service 1992a).

Definitions of forest health vary across the full range of land allocations and among land stewards of the various "specialty" disciplines. Forest Service standards of forest health that are specific to individual situations would help to establish monitoring strategies and procedures that could be used to help achieve the desired future conditions described in forest plans (Gast et al. 1991). These could serve as ecosystem endpoints. The rationale for monitoring is twofold: [1] monitoring plans that are described in individual national forest plans could be expanded to include funding and personnel necessary to adequately monitor forest health improvement projects, and [2] field personnel have reported that adequate standards and procedures for monitoring and reporting on forest health indicators are not in place.

Forest health monitoring reports have been published for three southern states (Bechtold et al. 1992) and the northeastern states (USDA Forest Service 1993a). Neither of these reports hinted at the significant increases in forest mortality (24% nationwide, with the highest increases in the south) from 1987 to 1991 reported by Powell et al. (1993) using Forest Inventory and Analysis data.

Environmental Monitoring and Assessment Program (EMAP)

The U.S. Environmental Protection Agency has designed the Environmental Monitoring and Assessment Program (EMAP) to monitor status and trends in the condition of major ecological resources throughout the nation (Norton and Slonecker 1990). This long-term effort is designed to gather indicators of ecological resources throughout the nation. EMAP will generate a database that can be used to respond to the growing demand for information about the environmental health of the country. The information will provide the means to characterize the condition of various ecosystems, as well as the type and location of changes in the environment. Simultaneous monitoring of pollutant exposure, habitat condition, and environmental changes will allow EMAP to assess the current status and geographic distribution of our ecological resources. It will also provide information needed to determine what proportions of these resources are degrading or improving, where, and at what rate. Analyses of the data will not only allow for an evaluation of the effectiveness of control and mitigation programs, but may provide an opportunity to detect impending environmental problems before they become critical or irreversible (U.S. Environmental Protection Agency 1993).

EMAP has identified seven ecological resource classes for monitoring. One of them is forest ecosystems. An almost unlimited number of potential measurements of forests are available for monitoring. Numeric criteria based on experience and expert judgement are available for forests, but these are difficult to justify objectively. EMAP has identified three high priority response indicators for monitoring. The EMAP program will use these "response indicators" to quantify and classify the condition of forests, and to identify forests in "subnominal" condition. Three response indicators are recognized as having high priority status: [1] visual symptoms of foliar damage, [2] tree growth efficiency, and [3] relative abundance of animals. It is important to note that these criteria are not ready for implementation (Riitters et al. 1990). We describe these and other indicators in the next section of this chapter, and in Chapter 14 use the two vegetation indicators to assess forest health conditions in Idaho.

The implementation plans for EMAP are detailed in Table 13-1. Idaho was scheduled to be added to the program through the establishment of permanent plots in 1993 (Burkman and Hertel 1992). The schedule has been put on hold. Idaho did not receive any funding to begin any aspect of the program (L. Livingston, review comment).

According to the U.S. Environmental Protection Agency (1993), EMAP is an environmental monitoring program, thus the vast majority of data collected will have spatial characteristics. These spatial data coupled with data from existing networks will be incorporated into the EMAP Information Management System. Given the nature of the data, the analysis of spatial relationships becomes one of the central themes of EMAP research. It is, therefore, of paramount importance to develop an efficient system for storage, retrieval, analysis, and reporting of spatial information in EMAP. A geographic information system (GIS) will be utilized throughout EMAP to accomplish these goals. GIS incorporates the components of computer cartography with analytical functions and a relational database management system to formulate a powerful set of tools for the storage, retrieval and analysis of large volumes of multi-disciplinary environmental data. Development of an efficient system for the storage and retrieval of EMAP spatial information will require close coordination between ecologists, data management experts and geographers. The EMAP GIS design will be an integral part of the overall EMAP Information Management System and must be designed to insure an efficient, timely, and an effective flow of spatial information throughout the EMAP system (U.S. Environmental Protection Agency 1993).

Concerns with EMAP, however, are that the sampling points are grid-based rather than ecosystem-driven, and that the variables collected do not address landscape-level

Table 13-1. States with permanent plots in the U.S. EPA's Environment Monitoring and Assessment Program (EMAP).

Year plots established	States
1990	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
1991	Alabama, Delaware, Georgia, Maryland, New Jersey, Virginia
1992	California, Colorado
1993 (planned)	Idaho, Minnesota, Texas, West Virginia, Wisconsin

attributes (R. Everett, review comments).

Choice of Indicators

The first step in measuring ecosystem health is identification of relevant indicators and acceptable ranges of parameters. Forty years of ecological research have identified many such variables and parameters, but there are several problems in selecting an appropriate set of them. First, each ecosystem has its own set of indicators and endpoints, and each must be assessed separately. Second, indicators and variables must be sufficiently dynamic to measure ecosystem change. Third, each scientist evaluating the ecosystem will choose variables depending on his or her specific interest and expertise (Haskell et al. 1992).

Many different categories of ecosystem components need to be considered, depending on the composition of a particular forest ecosystem. Selection of a representative set of indicators depends on three key factors. Indicators should be 1) closely related to parameters of interest, 2) effectively measurable, and 3) little affected by other parameters. While it is difficult to generalize about indicator selection because of the complex nature of ecosystems, indicators discussed in this section have been selected from hundreds of candidates and widely applied. Riitters et al. (1990) suggested that someday we may be able to identify a set of indicators that relates to everyone's perception of forests.

Environmental Monitoring and Assessment Program (EMAP). An indicator is defined by EMAP scientists (Hunsaker and Carpenter 1990) as a characteristic of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to the stressor, or degree of ecological response to the exposure. Indicators that represent ecosystem characteristics can be identified and quantitatively measured. The EPA recognizes three broad categories of indicators:

1) **Response indicator** - A characteristic of the environment measured to provide evidence of the biological condition of a resource at the organism, population, community, or ecosystem process level of organization.

2) **Exposure and habitat indicators** - Diagnostic indicators measured in conjunction with response indicators.

   Exposure indicator - A characteristic of the environment measured to provide evidence of the occurrence or magnitude of a response indicator's contact with a physical, chemical, or biological stress.

   Habitat indicator - A physical attribute measured to characterize conditions necessary to support an organism, population, or community in the absence of pollutants.

3) **Stressor indicator** - A characteristic measured to quantify a natural process, an environmental hazard, or a management action that effects changes in exposure and habitat.

Indicators for forest ecosystems can be subdivided into the seven categories described below. In some categories, individual indicators are identified. In others, a general description is provided.

Soil. Soil is a medium on the Earth's surface which has both abiotic and biotic characteristics and features. The interaction of the soil with other physical and biological processes results in the abundance and diversity of plants and animals within an ecosystem. Three indicators follow.

Microbial Activity - Soil microorganisms play a vital role in the retention and release of nutrients and energy in forested soils. Nutrient and energy fluxes influence the biological and chemical activity of an ecosystem and are sensitive to structural changes in that system (Riitters et al. 1990).

Litter Dynamics - Large quantities of nutrients circulate within a forest ecosystem. Although part of the annual requirements of plants can be met by reabsorption before the loss of tissues, the remaining nutrients must be obtained by uptake from the soil. The majority of soil nutrients is derived from the decomposition of organic litter, including woody material, insect frass, and fallen leaves. Thus litter dynamics, such as the rate and pathways of decomposition, are important determinants of ecosystem productivity and condition (Riitters et al. 1990).

Soil Productivity Index - Soil productivity is usually defined as the capacity of a given volume of soil to produce a vegetative response under a specified system of management (Riitters et al. 1990).

Water. Water is ubiquitous and essential in all life forms while being spatially and temporally limiting in many ecosystems. The quality of water flowing through the landscape is a barometer of ecosystem health. Three indicators follow.

Macroinvertebrate counts - The presence/absence and the abundance of certain aquatic invertebrates can provide a measure of health and complexity. This measure can be used to compare similar aquatic habitat in an ecological region. These organisms are sensitive to physical, chemical, and biological stressors; i.e., they can be used to assess taxonomic and trophic groups (including sensitive and tolerant species), and data can be aggregated to integrate species composition data into an index useful for interpretation of community abundance and condition and ecosystem health (Hughes and Paulsen 1990).

Routine Water Chemistry - This refers to identification and evaluation of a number of conventional chemicals and nutrients, particularly those of importance to aquatic life. Parameters are used to calculate trophic state and to assess such processes as eutrophication, acidification, and salinity (Hughes and Paulsen 1990).

Physical Habitat Features - Hydrological and physical changes—including sediment, large woody debris, temperature, streambank stability, and in-stream flows—can be measured to assess both morphological condition of stream or lake beds and banks and to assess suitability of these areas for spawning, rearing, and feeding by biota (Hughes and Paulsen 1990).

Vegetation. Woody plant vegetation is the defining characteristic of a forest ecosystem. Two vegetation indicators have been identified by EMAP as high priority response indicators of forests—visual symptoms of foliar damage and tree growth efficiency. A third indicator, understory vegetation, is a lower priority response indicator (Riitters et al. 1990).

Visual Symptoms of Foliar Damage - These are measures of the health of individual trees and populations in terms of pathological conditions, and they are measures of aesthetic quality. Foliar damage may range from discoloration to complete loss of foliage resulting from insects, disease, fire, or other disturbances that either weaken or kill the tree

(Riitters et al. 1990). Foliar damage, however, does not address shifting patterns of vegetation species composition or density, both of which are related to forest health.

It is also difficult to relate the number of trees killed or the extent of a defoliated area to the actual impact on forest health. This has led environmental groups to question the severity of insect damage. For example, Gast et al. (1991) reported that 53% of the forested area in the Blue Mountains national forests had been affected by defoliating insects, and provided no other measure of impact. Aplet (1992), forest ecologist with the Wilderness Society, expressed difficulty interpreting what this statement implied about forest health management. Indeed, the Forest Service subsequently reported (Associated Press 1993c) that precipitation has enabled portions of the Blue Mountain forests to recover, and defoliation during drought conditions may have spared many trees from death by causing them to become dormant during a period of stress.

When do visual symptoms of foliar damage suggest that a forest health problem exists? There is not yet any standard classification of crown density, crown vigor, and foliage for a tree or stand, primarily because the visual method of crown ratings is quite subjective (Anderson and Belanger 1986). Subjectivity is the major weakness of the European crown vigor method (UNEP and UN-ECE 1987). Applying crown vigor or other measure of canopy density to indicate forest health cannot be implemented at this time (Riitters et al. 1990). Given time, financial resources, and effort these problems can be overcome. Remote sensing and GIS-based analysis, although not "visual" assessments, could offer promise for the future.

Tree Growth Efficiency - This is a measure of the overall ability of trees to maintain themselves in an ecosystem, which is an obvious but sometimes overlooked condition for the perpetuation of forests. Periodic measurements of dimensional or biomass growth can be used, with an index for the capacity of growth, to construct a growth efficiency index. The literature indicates that certain levels of tree growth efficiency are associated with the probability of insect attack and mortality. These starting points can be refined with additional experience and research (Riitters et al. 1990).

Tree growth efficiency can be measured, either at the individual tree or stand level (see, for example, Waring 1983). For forest-wide health estimates, a more practical approach may be to use the growth and mortality data collected by the USDA Forest Service. Tree growth and mortality can be dramatically influenced by endemic and epidemic pest populations. Norris et al. (1993) suggested the relationship of mortality to growth as an indicator of forest health. In Chapter 14, we use existing tree growth and mortality data to assess forest health conditions in Idaho.

Understory vegetation - This can be a sensitive indicator of forest responses to environmental stresses. Measures of the amount and distribution of various life-forms can be summarized into useful indices. Two general parameters, species composition and abundance, should be measured to develop a quantitative assessment of ecological status. The exact methods will depend on the community type that is to be sampled (Riitters et al. 1990).

Animals. Vertebrate and invertebrate animals occupy the higher trophic levels of forest ecosystems, making them useful indicators of ecosystem condition. A major concern in using animals as indicators lies in correctly matching the organism to the landscape scale of interest, since virtually all animals are mobile to a greater or lesser degree. Some species, such as neotropical birds, may range so widely that they may be used as indicators of entire regional-scale ecosystems, although they may also prove to be useful indicators at the stand level within limited timeframes. However, their wide range and migratory patterns may reflect trends in wintering habitat rather than North America.

A particular value in using animals as indicators, particularly birds, lies in their widespread appeal to many segments of the public, resulting in a large volume of data collected in the same manner across broad geographic areas. An example is the annual Christmas bird counts taken across the nation by local groups affiliated with the National Audubon Society.

Relative Abundance - The most direct and easily understood application of using animals as indicators is a measurement of relative abundance. This measure can range from presence/absence to a precise census of entire populations within some defined area. Most appropriately, confirmation of presence plus some index to the number of individuals per unit area over a defined period of time is employed to measure relative abundance. Values for individual species can be aggregated or manipulated in many ways to derive estimates relating to forest ecosystem characteristics, such as site-specific measures of diversity, species richness, species evenness, and others (Patton 1992).

Demographics - Population demographics may provide an indicator of potential sustainability of ecosystems. Mobile species often require particular habitat features for species life functions (i.e., feeding, security, reproduction). Measurements of population productivity or other demographic indicators (e.g., age structure) may indicate the abundance and/or distribution of such critical habitat features, and with sufficient base-line data, may indicate changes in these features through time.

Morphological Asymmetry - Most animal species are constructed on a body framework of bilateral symmetry. That is, one half of the body is structurally a mirror image of the other. Asymmetry in body form is often an expression of concentration of toxins or pollutants at high levels in the trophic chain (Riitters et al. 1990). However, asymmetry may also reflect low genetic diversity caused by inbreeding in small isolated populations.

Physical Habitat Features - Physical habitat features, especially those known to provide habitat essential for particular life stages of specific organisms, provide a stationary indirect index to organism distribution. Physical habitat features should be assessed both in terms of presence/absence, number of sites, and distribution across the landscape (Patton 1992). Distribution and relative proximity of these features to each other and the presence of corridors allowing animals to move between separated sites (Harris 1984, Patton 1992; for an example, see Erickson and Toweill 1994) must be scaled to the specific organism(s) under consideration. Physical habitat features can include topographical features (for an example, see Irwin, 1994).

Ecosystem cycling. The cycling process of chemical elements within an ecosystem is fundamental to the maintenance of its components. Organisms depend on the availability of at least 20 elements of which all are required for life processes. The effects on accelerated removal or addition of contaminants on nutrient availability ultimately translates into effects on many other aspects of ecosystem structure and function (Campbell et al. 1990).

Landscape pattern. Landscape pattern addresses a larger area than some of the other categories or indicators. These indicators, by definition, assess broad landscape areas that could range from thousands of acres to several hundred thousand acres and more.

Habitat Proportions (Cover Types) - Determining proportions of various vegetation cover types in a landscape is a basic measurement when considering both extent and change in vegetation and associated animal composition and diversity (Harris 1984, Carpenter et al. 1990). Specific vegetation cover types or characteristics, such as riparian areas and wetlands, need to be considered at the landscape level as they provide special habitats associated with animal composition and diversity. Other indicators mentioned by the EPA that relate to habitat are patchiness and patch size (Carpenter et al. 1990).

Landform - Landform is generally described in a hierarchical framework including physical characteristics (e.g., mountains, valleys, plateaus, etc.) and their formative processes. Information on parent materials and their durability is a consideration. Landform directly influences other indicators, such as water, vegetation, and animals.

Non-native plants and animals. The introduction, even in small numbers, of non-native animal or plant organisms can pose a threat to forests. Their normal complement of biocontrol agents is usually missing in areas where they are introduced. Without these control agents, the introduced species may spread rapidly. If they impact native species, the resulting damage can be extensive. The presence of any introduced species should be evaluated carefully, as it may result in an unhealthy forest condition.

Blue Mountains Ecosystem Health Indicators

Scientists working on restoration of the Blue Mountains forests (Caraher et al. 1992) have identified nine ecosystem elements or indicators for assessing forest ecosystem health (see Table 13-2). Three indicators are seral stages in Douglas-fir and true fir climax forests, two are pine types with high density and low vigor, two are general indicators (available fuels and % of grassland and shrubland colonized by juniper) and two are watershed health indicators (riparian shrub cover and streambank stability). The application of these ecosystem health indicators was demonstrated in Figure 10-1.

Systems Approach and Modeling

Costanza (1992) said ecosystem health cannot be assessed quickly, cheaply, precisely, and without ambiguity. There is no health meter probe that can be inserted into an ecosystem to provide a readout of health. Assessing health in a complex system—whether an organism, an ecosystem, or economic system—requires judgment, precaution, and humility, but also a good measure of systems analysis and modeling in order to put all the individual pieces of the puzzle together to form a coherent picture (Costanza 1992). A significant problem in assessing forest ecosystem health is not only selecting the appropriate components, but assembling them in a conceptual framework or model. The current status of what EMAP scientists referred to as an "assessment framework" is depicted in Figure 13-1.

Ecosystem health modeling is a complex undertaking made especially difficult by the lack of data on many ecosystem components. Ecosystem components (labelled "values") indicated as having "high assessment reliability" in Figure 13-1 currently have data bases. Those with "moderate" or "low" reliability do not.

The lack of reference data on key ecosystem values—such as sustainability, quality, diversity, and aesthetics—associated with animals and vegetation make ecosystem health assessments more complex than human health assessments. Costanza (1992) said human health assessment relies on a compendium of known potential diseases, a huge body of reference data on the "standard human," and many types of diagnostic tools that make human health assessment possible without resorting to sophisticated computer modeling, primarily by reliance on the "expert system" of medical practitioners. To generalize this expertise and apply it to all kinds of systems requires systems modeling (Costanza 1992).

Although not addressing forest health, Costanza (1992) proposed a general index of ecosystem health made up of three components: vigor, organization, and resilience. Although he said vigor can be measured directly in most cases, there are several choices available for measuring forest ecosystem vigor. We use measures of mortality and growth to represent tree growth efficiency at a large scale in Chapter 14 because data were periodically available from 1952 to 1987.

Costanza (1992) suggested that network analysis and simulation modeling are two of the most promising avenues for developing organization and resilience components of the proposed health index. Both methods are relatively expensive to implement because of their large data requirements, but EMAP is being designed to collect much of the necessary data. EMAP will use remote sensing capabilities and computers to implement these methods, facilitating large scale analysis.

Table 13-2. Nine ecosystem elements or indicators for assessing forest ecosystem health in the Blue Mountains.

Douglas-fir/true fir climax forest

1. **Early Seral:** The percent of the climax fir forest that consists of forest openings and stands of young trees with small diameters (less than two inches) and has an open canopy (less than 60% closure).
2. **Late Seral Park-Like:** The percent of the climax fir forest that consists mostly of ponderosa pine or western larch, has been maintained by frequent underburns, and has less than 20% cover of understory trees.
3. **Late Seral Tolerant Multistory:** The percent of the climax fir forest that consists of stands with two or more canopy layers of Douglas-fir and true fir and which have less than 20% overstory cover of ponderosa pine or western larch.

Ecosystems dominated by pine species

4. **Ponderosa Pine - high density, low vigor:** The percent of the ponderosa pine stands, climax as well as seral, that are dominated by trees larger than 6 inches diameter at breast height and are susceptible to attack by bark beetles.
5. **Lodgepole Pine - high density, low vigor:** The percent of the lodgepole pine stands climax as well as seral, that are dominated by trees larger than 6 inches in diameter at breast height and which are susceptible to attack by bark beetles.

General indicators of ecosystem health

6. **Available Fuels** - The percent of the total above-ground forest biomass that consists of standing dead and down trees.
7. **Juniper-Grasslands** - The percent of the grasslands and shrubland that has been colonized by juniper.

Indicators of general watershed health

8. **Riparian shrub cover** - The percentage of stream length which has deciduous shrub cover.
9. **Streambank stability** - The percentage of stream length which has stable banks.

Source: Caraher et al. (1992).

Ecosystem health is also amenable to direct empirical testing. One approach might use various versions of the health index proposed by Costanza (1992) and apply it to systems for which there is some general agreement on health status—for example, humans or other organisms. To test their effectiveness it might be possible to judge which version did the best job of reflecting whatever health rankings have been agreed on. The best indices could then be applied to ecological systems with at least some confidence that they might represent the general health of the system. Although it will not be easy or simple, it is time to begin the messy, difficult, but essential task of assessing the health of ecological systems (Costanza 1992).

The complexity of natural phenomena has always been a problem for scientists, who traditionally through reductionism describe phenomena in simple or causal hypotheses. This is generally the appropriate way to advance knowledge about systems about which much is known. It is not generally an appropriate method for investigating the overall functioning of little understood ecosystems and the impact of management on them. Simple causal explanations for complex phenomena rarely contribute much towards understanding them. The alternative approach

ENVIRONMENTAL VALUE	RESOURCE TYPE				
	Soil	Water	Air	Vegetation	Animals
Sustainability	□	□	—	□	□
Productivity	—	—	—	■	■
Aesthetics	□	□	■	□	□
Diversity	—	—	—	▨	▨
Extent	■	■	—	■	▨
Utilization	—	—	—	■	■
Contamination	■	—	■	■	■
Quality	□	—	▨	□	□

ASSESSMENT RELIABILITY

■ High ▨ Moderate □ Low — Not Applicable

Figure 13-1. Current status of assessment framework for forests in U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP).

Source: Palmer et al. (1992).

is to construct a comprehensive model of complex phenomena, and use it to make predictions about how the system will respond to disturbance (Kimmins 1987). This modeling task is beyond the capability of current data bases and understanding of ecological processes.

Modeling is the process of developing a tool that is generally used for predictive purposes. Sometimes modeling is undertaken as an exploratory exercise to see what is known and unknown about a particular system. The value of a model can be either what the model can do, or what is learned during its construction, or both. Regardless of the original purpose of modeling, one should be skeptical of the predictions generated by a model, because the level of understanding of complex systems and the availability of appropriate data are limited (Kimmins 1987).

What is needed is a modeling framework that simultaneously simulates multiple insect and disease agent dynamics, fire conditions, and plant, wildlife, and fish habitat conditions according to time-step projections of changes in vegetation structure and composition. Such a model does not exist (Everett et al. 1993). In order to simplify the complexity of forest ecosystems, the key to developing such a model is selecting the appropriate ecosystem components.

Woodley (1993) suggested four modeling

approaches for operationalizing the concept of ecosystem health: [1] reductionist, [2] integrated, [3] threat specific, and [4] hypothesis testing. He preferred a combination of integrated and threat-specific approaches to either the reductionist or hypothesis testing models for ecosystem monitoring. Shackell et al. (1993) outlined an aquatic systems monitoring program model as a case study example.

The USDA Forest Service recognizes that careful attention needs to be given to social considerations in ecosystem monitoring. Formal and informal means of monitoring social needs and expectations of resources and landscapes include public involvement and scoping processes in forest-and project-level planning. Conflict resolution exercises provide some further insights into social expectations, but on balance public land management has not reflected social expectations and values, as evidenced by endless appeals of forest plans, timber sales, and litigation surrounding virtually all significant management actions (Everett et al. 1993).

A primary assumption of an integrated monitoring approach under ecosystem management is that most socioeconomic and ecological values and expectations of managed forests can be expressed in terrestrial and aquatic landscape patterns and processes. Monitoring should evaluate whether landscape management objectives are achieved, whether social expectations are met, and whether they are compatible or in conflict with long-term sustainability of ecosystems (Everett et al. 1993).

Toward Coherent Monitoring

Once the key parameters for an ecosystem have been identified, a major effort is required to determine "normal" ranges. Medical practitioners and veterinarians routinely consult published tables giving normal values for key physiological attributes. Ecologists are hindered by the scarcity of such information. Large-scale ecosystem monitoring efforts began in the 1970s, encouraged by the International Biosphere Program to establish values characteristic of the structure and functions of the earth's major ecosystems (Rapport 1992b). Unfortunately, little if any of this work was done in Idaho.

A monitoring program is needed to identify changes in conditions. After key parameters or indicators have been identified, their historic range should be determined. This will provide a reference point for the establishment of comparison standards. Medical practitioners routinely consult published tables giving normal values for key physiological attributes. Ecologists are hindered by the scarcity of such information, but the concept of historic range of variability (see Morgan et al. 1994) can be used to assist in the development of standards or indices for assessing forest health.

In their review of forest health monitoring strategies, Everett et al. (1993) pointed out that current monitoring is often piecemeal rather than part of a coherent strategy for all species, processes, and ecosystems. Because forest ecosystems depend on a complex relationship of abiotic and biotic elements, monitoring should integrate selected elements or indicators with societal values to assess effectiveness in conserving biological diversity, long-term site productivity, and the sustainability of producing resources for human needs (Everett et al. 1993).

Hunter (1990) proposed a coarse filter approach to ecosystem monitoring. That approach promotes biodiversity by maintaining ecosystem structure and components as well as associated species and processes within the landscape. To supplement the coarse filter strategy, Everett et al. (1993) recommended a three-part fine-filter monitoring strategy focused on: 1) landscape structure and composition; 2) threatened, endangered, and sensitive species and unique habitats; and 3) disturbance regimes, disturbance effects, and hazards.

This monitoring approach could allow for more efficiency and effectiveness in data collection, analysis, and interpretation when based on a hierarchical landscape system such as the National Hierarchy of Ecological Units For Ecosystem Classification (USDA Forest

Service 1993b). The various scales of ecological landscape units can be nested into such groups as: potential vegetation, soils, landform, hydrology, biological life and disturbance patterns. The physical and biological processes and responses of nested units to disturbance are similar. This allows extrapolation of data and assists in determining effects on societal values.

Norris et al. (1993) pointed out that forest inventories have historically been conducted at an extensive scale for the purpose of measuring overall conditions and trends of timber resources, but do little to reflect the needs of ecosystem management. More comprehensive and intensive inventories are necessary to include commodity and non-commodity values and estimates of changes in forest health, biodiversity, and sustainability. With detailed ecosystem characterization of stands, streams, habitats, and landscapes, improved forest planning and decisions will result (Norris et al. 1993).

The forest products industry has recognized the need to improve and expand inventory information on ecosystems and noncommodity values, and recommended this as one of six high priority areas for improving forest inventories. The industry has also recommended that the scope of the USDA Forest Service Inventory and Analysis project be expanded to provide basic stand structure, habitat, and forest health information that can be useful in addressing contemporary issues (American Forest and Paper Association 1993).

Because ecosystems are complex, one recommendation of Everett et al. (1993) has much merit: a short list of important monitoring variables or indicators should be identified to accomplish representative and cost-effective monitoring. Until that is done, monitoring will continue to be piecemeal. Without a coherent monitoring program we will not know whether the health of forest ecosystems is improving, stable, or declining.

What Measures of Forest Health Are Appropriate in Idaho?

As a minimum, the assessment of forest ecosystem health will require measures of vegetation, terrestrial wildlife, and watershed.

As a measure of vegetation condition, both visual symptoms of foliar damage and tree growth and mortality have existing data bases and reflect different aspects of forest ecosystems. Visual symptoms of foliar damage indicate the effects of biotic and abiotic stressors, and can be assessed with remote sensing techniques, thus can cover large areas at frequent measurement intervals. Tree growth and mortality data from periodic forest inventories exist and can be effectively used, as we demonstrate in Chapter 14. O'Laughlin et al. (1994) also identified the presence of non-native vegetation (as well as wildlife) as a key indicator of ecosystem condition.

As a measure of wildlife condition, relative abundance has been recommended as a high priority indicator by the EPA, but the concept of indicator species is not widely accepted by wildlife biologists (see Chapter 9). Physical habitat features may be a more practical indicator, but the presence of habitat does not guarantee that animals will occupy it, so some measure of presence will also be necessary (see Erickson and Toweill 1994). The hard part is selecting appropriate species, which will likely be successfully done only through interaction with public stakeholders or customers. Irwin (1994) said the habitat selection process used by wildlife could perhaps be used in ecosystem assessment if wildlife-habitat models were improved by probing the interactive effects of landforms, soils, and vegetation on the wildlife selections process, using remote sensing and GIS-based analysis. The presence of non-native species may be a key indicator of ecosystem condition.

As a measure of watershed condition, physical habitat features are probably the most important consideration. Water chemistry and macroinvertebrates are also useful indicators. The selection of watershed indicators will need to be tailored to specific sites. Water courses are highly variable, and it is an oversimplification to expect one measure to adequately represent all watersheds.

Conclusions

Forest health provides a framework for measurement and evaluation of ecosystem indicators. Individuals may come to similar conclusions about the condition of one ecosystem component based on an objectively measured indicator, but the value-based aspects of forest health, which cannot be objectively measured,will be repeatedly debated.

We conclude with this summary of major points:

- Objective indicators of forest ecosystem condition can be specified and measured, but forest health assessments contain subjective value judgments which must be clearly recognized.
- At least three judgments need to be made: [1] selecting a representative set of indicators to measure ecosystem health—vegetation, animals, and watershed as a minimum; [2] developing standards for using indicator measures to assess conditions; and [3] resolving value conflicts regarding these judgments.
- The presence of non-native vegetation and wildlife may be a key indicator of ecosystem condition.
- Forest scientists and managers, working with their customers, can identify, define, and determine ranges of desired conditions for a set of measurable characteristics in each forest ecosystem that can be useful in helping evaluate the condition of the forest at any time, in relation to those desired conditions.
- Comprehensive and intensive inventories of a short list of indicators representing commodity and non-commodity values will improve forest health assessments, as well as forest planning and management decisions, by enabling understanding of ecosystem characteristics of stands, habitats, streams, and landscapes.

Chapter 14. Idaho Forest Conditions—Trend Analysis

Is there a forest health problem in Idaho? If so, how compelling is the problem? Replies to these questions depend on how forest health is defined and on the selection of criteria to measure the health of the forest. We will not attempt to define when a forest health "problem" may or may not exist. As is true in other health contexts, it may be easier to identify when a forest is in an unhealthy condition than it is to define exactly what healthy means. Thus, avoidance of unhealthy conditions is perhaps a more practical management approach than the attainment of healthy conditions.

According to the U.S. Environmental Protection Agency, three forest ecosystem response indicators have been identified as high priority (Riitters et al. 1990). A wealth of data has been collected that relates to two of these indicators—tree growth efficiency and visual symptoms of foliar damage. There is a lack of adequate data for the third indicator—relative abundance of wildlife. The data on foliar damage are highly variable, making the determination and interpretation of a baseline range difficult. These data are weakly related to precipitation or wildfire data.

Data on timber resources have been collected periodically on permanent plots established by the USDA Forest Service on all forest ownerships in the 1950s. Inventory data are used to determine changes in Idaho tree species composition. Inventory data on annual growth and mortality provide a rough measure of tree growth efficiency, and have been linked to forest health by Smith (1990), Marsden et al. (1991), and Norris et al. (1993). We used trends in growth and mortality data to establish a baseline range for the Inland Northwest and to compare more recent data on mortality rates in Idaho. This analysis of forest conditions is an important beginning for forest health assessment, but limited because it only deals with timber resources.

Our findings, presented in this chapter, reveal significant changes in species composition. Recent mortality estimates for some Idaho national forests are much higher than the upper limit of the range. On the Boise and Payette National Forests in southwestern Idaho, annual mortality exceeds annual growth. Recent inventories of national forests in northern Idaho show mature stands have mortality well above the baseline regional range, which projects into a negative net growth situation. Recent inventories of private and other public forests in northern Idaho do not show similarly elevated mortality in mature stands.

Timber and Timberland Trends

To put our analysis of conditions in Idaho's forests in context, it is instructive to review forest conditions nationwide and then compare Idaho to other states in the Inland Northwest, as well as the nation as a whole.

Nationwide trends. Prior to European settlement, forests covered roughly 950 million acres, or 42% of the United States (Figure 14-1). Approximately 850 million acres were timberlands, defined as forests physically and administratively capable of producing at least 20 cubic feet of wood per acre per year. The original American forest contained an estimated 5 trillion board feet of sawtimber. Today roughly one-third of the nation is covered by forests, with most of that in the timberland category. Sawtimber volume is less than 60% of what it was originally.

Sedjo (1991) stated that by many measures, America's forests are now in the best condition since the beginning of the twentieth century. The "favorable" condition of the nation's forests today is remarkable, considering the tremendous pressure people have historically placed on forests. From relatively undisturbed conditions in pre-colonial days, many forests went through rapid conversion to agricultural lands during the mid-1800s and early 1900s that were abandoned. As Figure 14-1 illustrates, forest stocks have recovered since then, demonstrating their serviceability and resiliency (Sedjo 1991).

Forests are vegetative systems capable of reestablishing themselves after disturbance

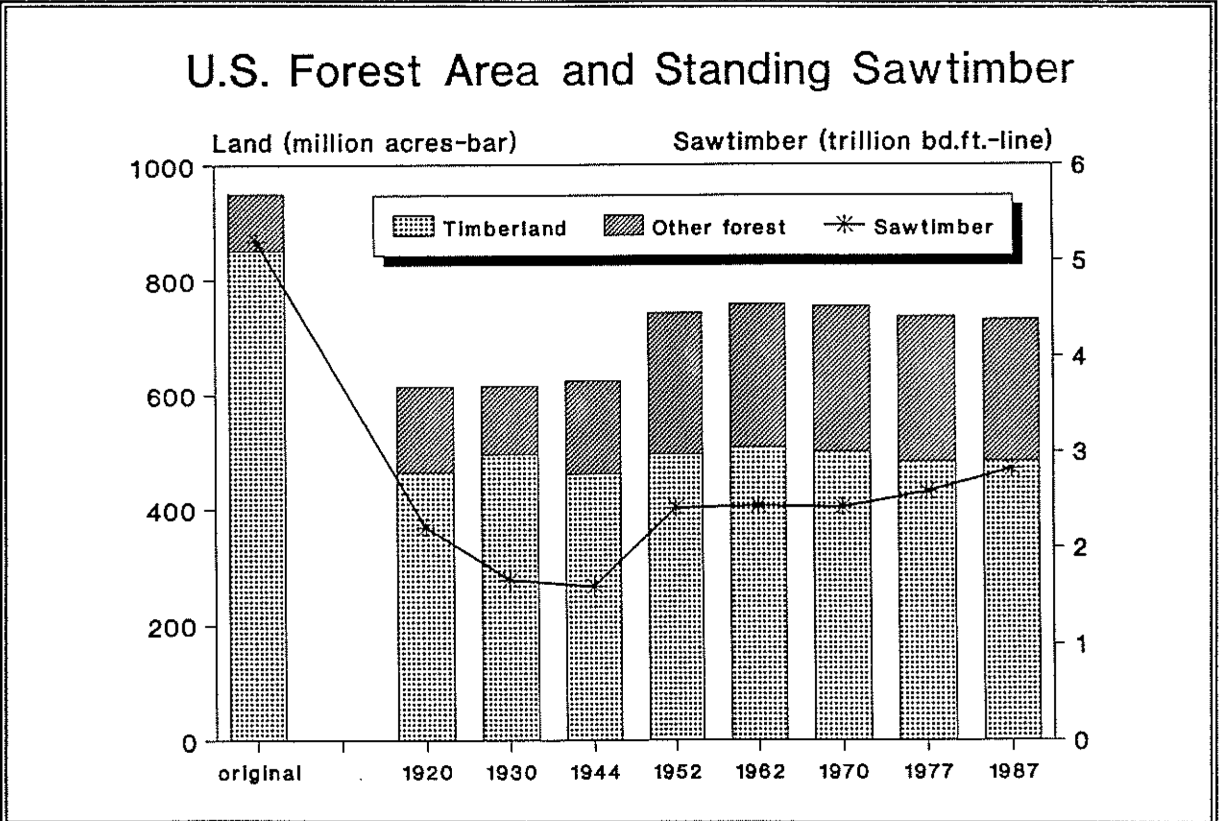


Figure 14-1. U.S. forest land area and standing sawtimber volume trends.

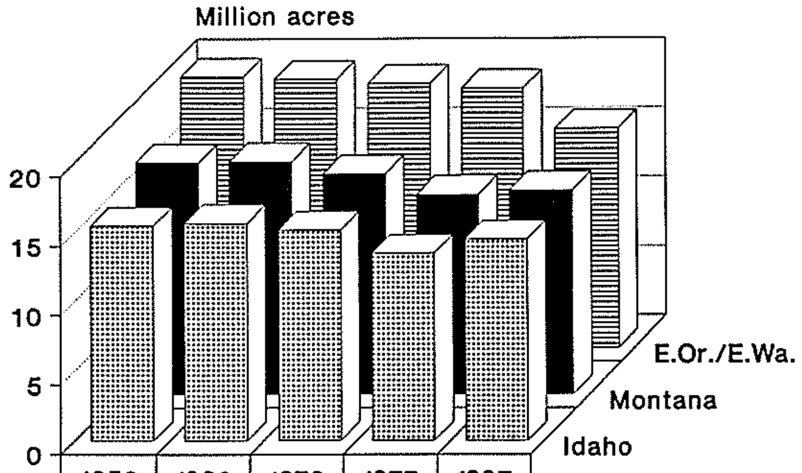
Sources: Clawson (1979), Williams (1984), USDA Forest Service (1982), Waddell et al. (1989).

from fire, pests, logging, or grazing. In fact, destruction and restoration are components of a continuing natural cycle in these complex ecosystems. Despite the stresses inflicted by humans, American forests showed an "amazing resilience." These systems have survived natural catastrophes in the past, and demonstrated the capacity to recover from the impacts of logging and agriculture (Frederick and Sedjo 1991). With management effort, the natural resilience of forests may be enhanced.

Inland Northwest trends. Timberland area, timber growing stock volume by species, and growth and mortality data are available at periodic intervals between 1952 to 1987 (USDA Forest Service 1958, 1965, 1973, 1982, Waddell et al. 1989, Waddell 1992). Growing stock includes all live trees more than 5 inches in diameter at breast height. Comparable data prior to 1952 are not reliable or consistent.

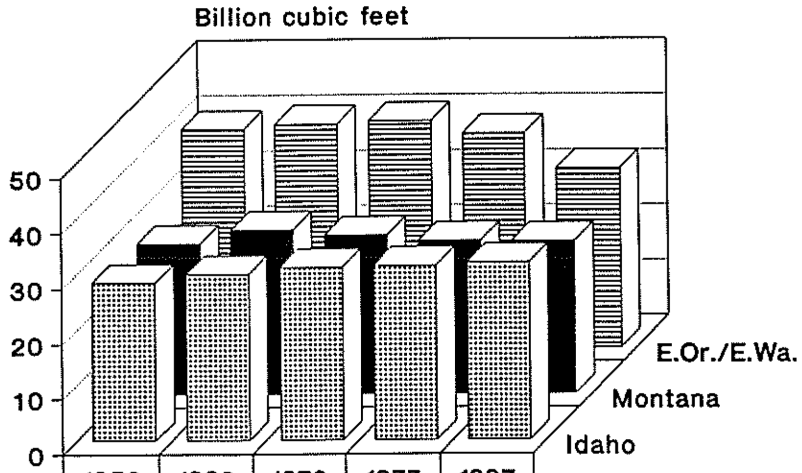
Timberland and timber growing stock volume data for all ownership categories in Idaho, Montana, and the eastern portions of Oregon and Washington are displayed in Figure 14-2. For comparison purposes, trends for the entire United States during the same period are presented as tabular data at the bottom of Figure 14-2. The timberland area trends in Figure 14-2 (a) indicate that Idaho timberland area declined by one million acres between 1952 and 1987. Montana had approximately the same amount of timberland as Idaho in 1987, but declined by two million acres. Eastern Oregon and Washington—that is, the portions of these states east of the Cascade Mountains taken together, or what the U.S. Forest Service calls the Ponderosa Pine region (Waddell et al. 1989) or the "eastside" region (Everett et al. 1993)—had slightly more timberland area in 1987 than either Montana

(a) Timberland Area Trends



	1952	1962	1970	1977	1987
E.Or./E.Wa.	19.6	19.4	19.1	18.7	15.8
Montana	16.7	16.8	15.9	14.4	14.7
Idaho	15.5	15.7	15.2	13.5	14.5
United States	509	515	504	491	483

(b) Softwood Timber Trends



	1952	1962	1970	1977	1987
E.Or./E.Wa.	39.7	40.6	41.1	38.8	32.5
Montana	27.4	29.8	28.8	27.7	27.6
Idaho	28.7	30.2	31.3	31.6	32.1
United States	430	448	458	464	451

Figure 14-2. (a) Timberland area and (b) softwood timber trends in Idaho, Montana, and the eastern portions of Oregon and Washington, 1952-1987, with U.S. data for comparison.

or Idaho, but declined by more than three million acres. All of these states are collectively known as the Inland Northwest region. The trend across the United States is similar, with a slight decline in timberland from 1952 to 1987.

Also depicted in Figure 14-2(b) is the softwood timber growing stock volume. Idaho has slightly more growing stock than Montana, and almost as much as the eastern Oregon and Washington region. Timber growing stock volume in Idaho increased by 12% from 1952 to 1987; volume in Montana remained relatively constant. Timber growing stock volume in eastern Oregon and Washington declined by 18% during the 35-year period. This indicates a situation in the "eastside" forests that is not currently evident in Idaho, Montana, or the rest of the United States.

Changes in Idaho Forest Types

Idaho has 5 of the 22 major forest types in the United States recommended by the Environmental Protection Agency (Riitters et al. 1990) for monitoring to assess forest health. They are Douglas-fir (27.9% of the Idaho total), fir/spruce (27.6%), lodgepole pine (13.3%), ponderosa pine (9.6%), and western white pine (4.3%). These five forest types represent 82.7% of all Idaho growing stock volume (Benson et al. 1987).

Figure 14-3 illustrates changes in the composition of tree species in Idaho forests since 1952. The back row in Figure 14-3(a) shows that Douglas-fir has increased slightly, holding its position as the largest component of Idaho forests. Figure 14-3(b) shows Douglas-fir increased by roughly 1.2 billion cubic feet (top scale) or 15% (bottom scale). The second largest component is the aggregation for Engelmann spruce, western larch, and other softwoods, primarily western redcedar and western hemlock. Taken together, spruce, larch, cedar, and hemlock increased by more than 30% from 1952 to 1987. The next component depicted in the illustration is true firs, consisting mainly of grand fir but including subalpine fir and a small amount of white fir. The true fir component has increased by 60%. Lodgepole pine increased almost 40% during the 35-year period of analysis.

Historically, the most important timber species in Idaho were ponderosa pine and western white pine. Both have declined since 1952, ponderosa pine by 40% and western white pine by 60% (Figure 14-3). Byler et al. (1994) estimated that the extent of western white pine may now be only 10% of what it was in 1900.

Based on these species changes, it is obvious that something significant has happened in Idaho's forests. Ponderosa pine has been reduced because it is a desirable timber species. Through the combined effects of fire exclusion and timber harvesting, Douglas-fir has invaded sites once occupied by ponderosa pine. Western white pine, also a desirable timber species, has been reduced primarily by the introduction of the exotic white pine blister rust fungus in the region in the early 1900s. These changes will be the subject of Chapter 15.

Figure 14-3(b) depicts the same data in a different way, and shows that growing stock volumes of both western white pine and ponderosa pine have declined by almost 2 billion cubic feet from 1952 to 1987. During that period, the true firs increased about 2.7 billion cubic feet. Spruce, larch, and other softwoods increased approximately 1.7 billion cubic feet. Lodgepole pine and Douglas-fir have both increased more than 1 billion cubic feet.

Western white pine and ponderosa pine together have declined by almost 4 billion cubic feet, while true firs and Douglas-fir have increased by a like amount. The increases in lodgepole pine and other softwoods, therefore, represent about 3 billion cubic feet of net volume increase (or 12%) in Idaho's forests since 1952.

Tree Growth and Mortality Analysis

In order to insure scientific credibility, a quantitative approach toward ecological indicators is preferred when feasible. Indicators should also be clearly

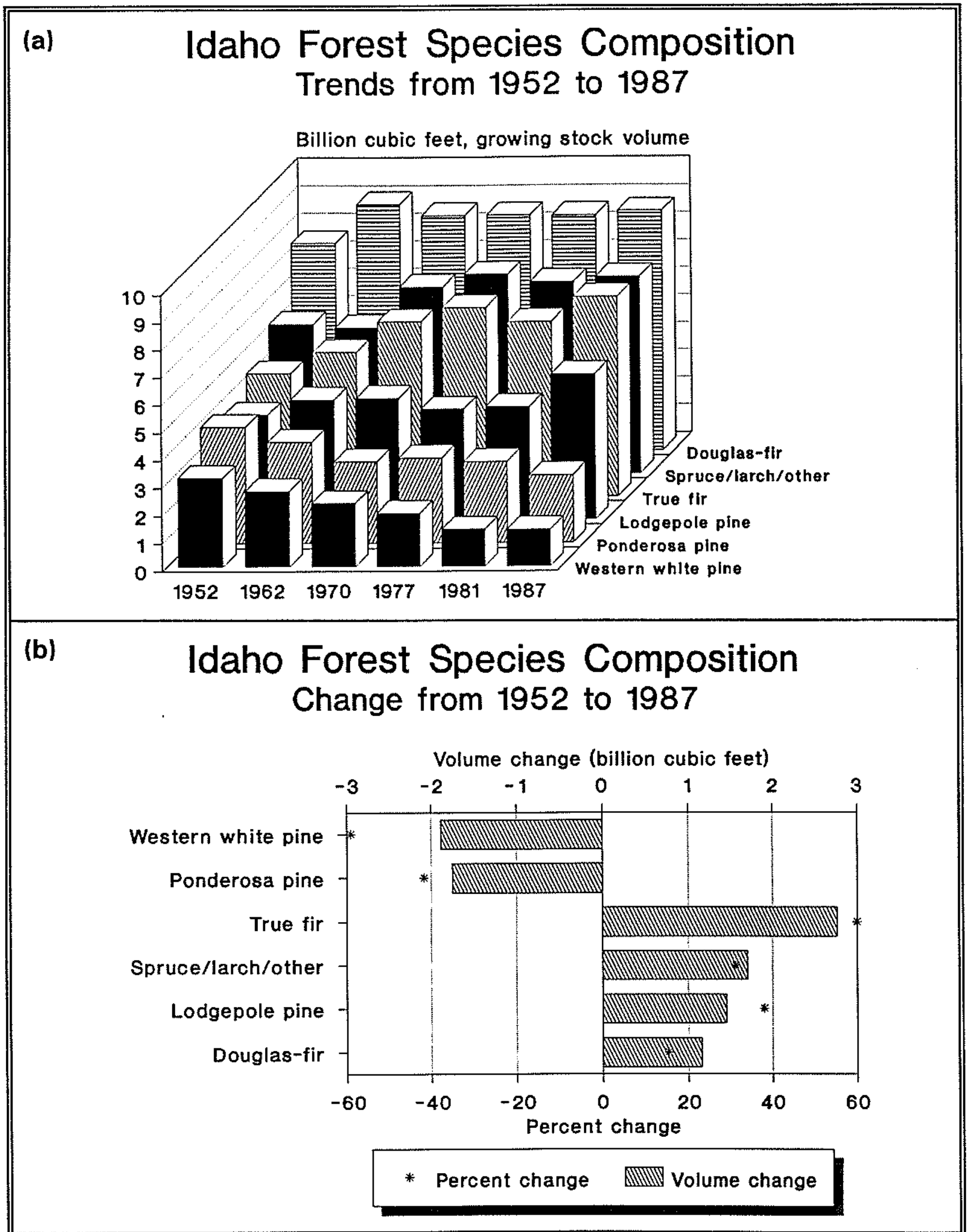


Figure 14-3. (a) Trends in Idaho forest tree species composition, 1952-1987; (b) with volume and percent changes by species.

understandable by both the public and decision makers to be of value (Marshall et al. 1993). The relationship of forest growth and mortality as a rough measure of tree growth efficiency is both quantifiable and understandable. In addition, a national database dating back to 1952 does exists.

Tree growth efficiency is one of the Environmental Protection Agency's three high priority response indicators for monitoring forest health. According to EMAP scientists (Riitters et al. 1990), "This is a measure of the overall ability of trees to maintain themselves in an ecosystem, which is an obvious but sometimes overlooked condition for the perpetuation of forests."

There are several ways to measure tree growth efficiency. Given adequate resources, tree growth efficiency can be measured either at the individual tree level or at the stand level (Marshall 1993). For large-scale health estimates, a more practical alternative may be to use the growth and mortality data collected by the USDA Forest Service. The relationship of tree mortality and growth rates to forest health was made by Smith (1990): "One useful index of forest decline is reduced stand growth per unit area of ground."

Tree growth and mortality can be dramatically influenced by endemic and epidemic pest populations. Marsden et al. (1991) suggested using forest-wide data collected during periodic inventories associated with the land management planning process on national forests. As they said, accurate quantitative measures of the presence, severity, and impact of pests are needed to make sound resource management decisions. The relationship of mortality to growth also has been suggested as an indicator of health by Norris et al. (1993) in the Society of American Foresters task force report on Sustaining Long-term Forest Health and Productivity.

What rates of tree growth and mortality may be expected in the Inland Northwest? What are the "average" rates, and how do current rates compare to past averages? How do growth and mortality rates in Idaho compare to other regions? In the Inland Northwest, mortality ranged from 10 to 12 cubic feet per acre in 1986 (Waddell et al. 1989, Waddell 1992), or 11% to 33% higher than the nationwide average. A baseline may be established by using a regional trend comparison approach similar to Figure 14-2 to analyze annual tree growth and mortality.

A note on statistical reliability. The periodic timber resource inventories conducted by the USDA Forest Service are sample data and therefore have associated variability measured as standard errors. The scale of the estimate affects the standard error. Generally, as the area covered becomes larger, more sample points are included and the standard error becomes smaller. Furthermore, estimates of timberland area made at the same scale as timber statistics—volume, annual growth, and annual mortality—have smaller standard errors, indicating less variability. Timber volume estimates have slightly smaller standard errors than annual timber growth estimates. Annual mortality estimates have the largest standard error. In Idaho, mortality standard errors are two to three times that of annual growth (Benson et al. 1987, Wilson and Van Hooser 1993).

Table 14-1 displays the published information on standard errors from the state, regional, and national data presented in Figures 2 and 4. They are expressed as a percentage range of the estimate, computed with a 67% confidence interval. No standard errors for annual growth or mortality were given in the source document, nor were standard errors provided in more recent region-wide inventory reports.

Table 14-2 displays the published percent standard errors for timber statistics in Idaho, also computed with a 67% confidence interval. No published standard errors for individual national forests or aggregated national forest data for Idaho were located in the literature.

From the published standard error of ± 10.3% for mortality on private and non-national forest public lands (4.5 million acres or 33% of Idaho timberlands) it can be assumed that individual national forests will have a standard error of at least ± 10% for mortality estimates. Mortality estimates have a

Table 14-1. Percent standard error of timber statistics for the Inland Northwest, 1977.

	Idaho	Montana	Eastern Oregon	Eastern Washington	Rocky Mountain Region	United States
Timberland area	± 0.9%	± 0.7%	± 0.7%	± 0.9%	± 0.5%	± 0.1%
Growing stock volume	± 1.3%	± 1.9%	± 1.5%	± 1.4%	± 0.5%	± 0.3%

Source: Data from USDA Forest Service 1982.

Table 14-2. Idaho softwood timber statistics and percent standard error on private and other (non-national forest) public forest lands, 1987.*

	Private and other public forests		National forests		Total
	Timber volume	Percent standard error	Timber volume	Percent of total*	Timber volume
	------------(timber volumes in billion cubic feet)----------				
Net volume	8.648	± 2.5%	23.440	73%	32.088
Net annual growth	0.244	± 3.7%	0.463	66%	0.706
Annual mortality	0.038	± 10.3%	0.120	76%	0.158

* Published standard errors for Idaho national forests are unavailable.
Source: Data from Benson et al. (1987), Waddell et al. (1989), Waddell (1992).

standard error three times as great as growing stock volume on non-national forest lands (Table 14-2), and volume estimates on all Idaho timberlands had a standard error of ± 7.3% per billion cubic feet (USDA Forest Service 1982). Therefore by extra-polation, standard errors for mortality on individual national forests may be at least ± 20%.

USDA Forest Service plant pathologists Jim Byler and Sue Hagle (pers. comm.) believe that mortality figures in forest inventory publications and forest plans are systematically underestimated. Based on their professional estimates of mortality using permanent plots that have been remeasured in the national forests in northern Idaho, Byler and Hagle feel that mortality figures in forest inventory publications and forest plans are underestimated by much more than 20%. They said it is difficult for professional foresters, let alone the temporary personnel who measure inventory plots, to tell whether or not dead trees have succumbed within the last five years. Partridge and Bertagnolli (1993) also mention the difficulty field personnel have estimating mortality from root disease.

Annual growth and mortality trends. As revealed in Figure 14-4, tree mortality in

Idaho has ranged from 115 to 202 million cubic feet per year during the six measurement periods from 1952 to 1987. No data have been compiled since 1987, the year the recent drought in the Inland Northwest began. During this same time, net annual growth—a measure of growth with mortality deducted from it—increased more than 70%, from 412 to 706 million cubic feet per year. For comparison purposes, during the same time period annual removals—primarily harvests of useful timber products—increased 55%, from 233 to 360 million cubic feet per year. A similar pattern is evident in Montana. In eastern Oregon and Washington, the picture is somewhat different, as mortality actually declined slightly from 1952 to 1987. Net annual growth increased during the period, but removals increased much faster, almost doubling during the 35-year period. In 1977 and 1987 annual removals exceeded net annual growth of timber in the eastside forests of Oregon and Washington. In comparison, softwood trends across the United States reveal fairly constant mortality, a substantial increase of 66% in net annual growth, and an increase of 24% in timber removals (Figure 14-4). As a footnote, Idaho and Montana growth and mortality data for 1952, 1962, and 1970 in Figure 14-4 are estimates that were necessary because of revisions in published data (see explanation in USDA Forest Service 1982, p. 334).

Idaho national forests.—Idaho's national forests represent 40% of the land area in the state. These public lands, managed by the U.S. Forest Service, include two-thirds of the timberland acreage (67%) and almost three-fourths (73%) of the forest growing stock volume in Idaho (Waddell 1992). In Montana, 56% of the timberlands and 67% of the forest growing stock volume are in national forests. In eastern Oregon and Washington, national forests include 48% of the timberlands. It is not possible to tell from published statistics how much of the growing stock volume is in the eastside national forests. For the nation as a whole, national forests have almost 18% of the timberland acreage and 41% of the softwood growing stock volume (Waddell et al. 1989).

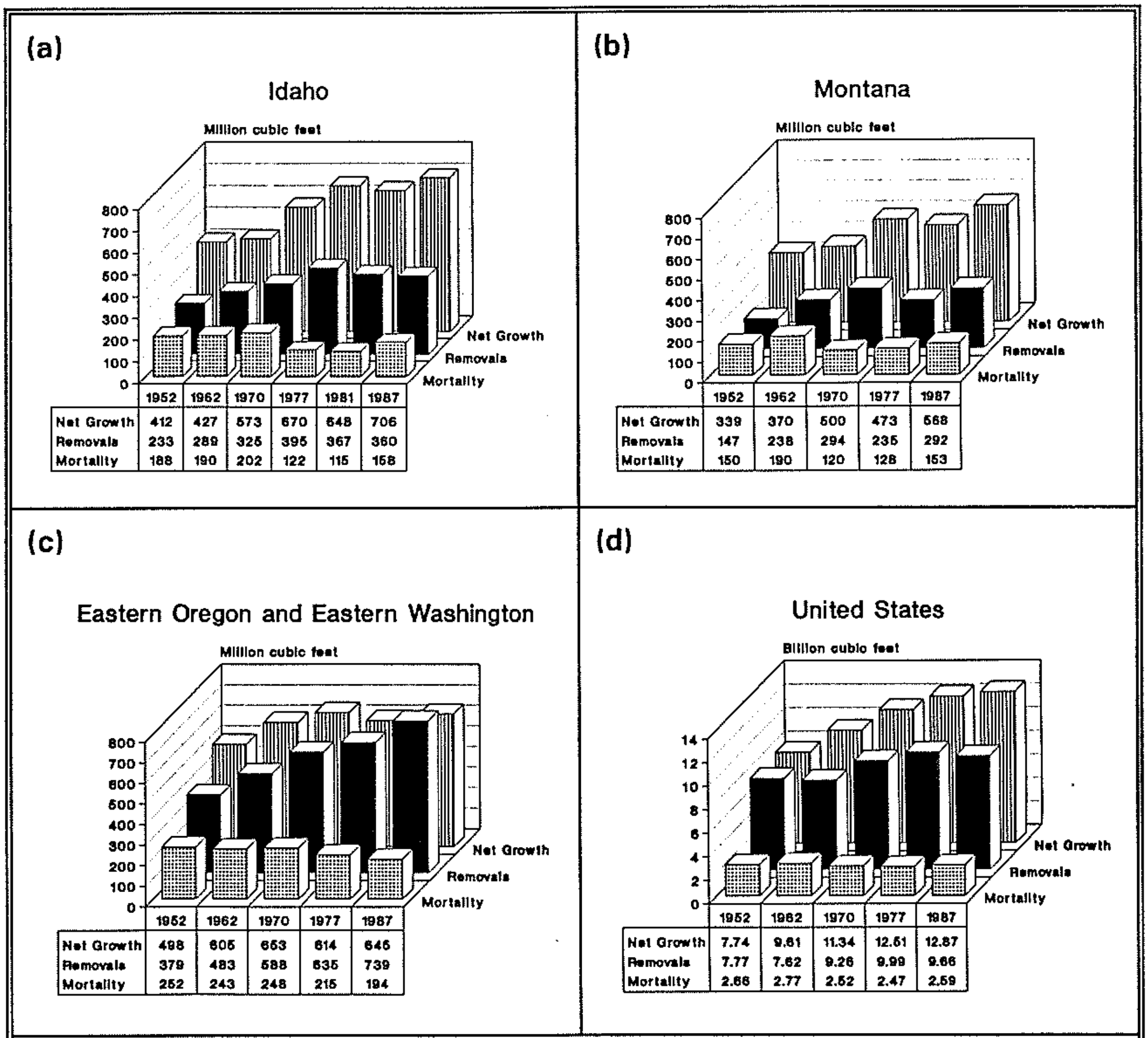
Each national forest conducts its own inventory on its own time schedule. Data on growing stock volume and annual growth and mortality are available in the forest plans for each of Idaho's national forests, and are used in this analysis. Inventory on other timberlands in Idaho is collected by the Research branch of the U.S. Forest Service.

Data on growing stock volume and annual growth and mortality have been extracted from the forest plans for each of Idaho's national forests. These data are displayed in Table 14-3 and analyzed in Table 14-4. These data are not directly comparable because they were collected at different points in time during the 1980s.

Public concern about forest health in Idaho is greatest in southwestern Idaho. The reason for this is revealed by analyzing the growth and mortality data from the forest plans. Averaged across all ten national forests, mortality was 18.3% of gross annual growth. Of the five national forests that have more than 2 billion cubic feet of growing stock volume, the Boise and Payette National Forests had, respectively, mortality at 31.3% and 24.9% of gross annual growth, significantly above the average. Of the five other national forests, the Targhee, with 1 billion cubic feet of growing stock volume, had mortality at 28.3% of gross annual growth (Tables 14-3 and 14-4).

The Boise and the Payette National Forests, along with Boise Cascade Corporation, are the largest timberland owners in southwestern Idaho. Growth and mortality trends for the Boise and Payette National Forests are depicted in Figure 14-5.

For the Boise National Forest, four data points from 1954 to 1992 are depicted in the leftmost portion of Figure 14-5. The first three sets of data for 1954, 1979, and 1987 were provided to us from the inventory records on file in the Forest Supervisor's office. Because of the absence of current inventory data, gross annual growth for 1992 was estimated using least squares linear regression. The estimate for 1992 is slightly less than 1987 inventory data. Mortality trend data indicated a slight decrease from 1954 to



(a) Idaho

	1952	1962	1970	1977	1981	1987
Net Growth	412	427	573	670	648	706
Removals	233	289	325	395	367	360
Mortality	188	190	202	122	115	158

(b) Montana

	1952	1962	1970	1977	1987
Net Growth	339	370	500	473	568
Removals	147	238	294	235	292
Mortality	150	190	120	128	153

(c) Eastern Oregon and Eastern Washington

	1952	1962	1970	1977	1987
Net Growth	498	605	653	614	646
Removals	379	483	588	635	739
Mortality	252	243	248	215	194

(d) United States

	1952	1962	1970	1977	1987
Net Growth	7.74	9.61	11.34	12.51	12.87
Removals	7.77	7.62	9.26	9.99	9.66
Mortality	2.66	2.77	2.52	2.47	2.59

Figure 14-4. Softwood timber annual net growth, mortality, and removal trends in (a) Idaho, (b)Montana, and (c) the eastern portions of Oregon and Washington, 1952-1987, with (d) U.S. trends for comparison (U.S. data at larger scale).

Table 14-3. Idaho national forests: timber growing stock volume data on acres suitable for timber production.

National Forest	Forest Plan Date	Total Acres[1]	Acres Suitable for Timber Production	Timber Growing Stock Volume	Net Annual Growth[2]	Annual Mortality
				(million cubic feet)		
Panhandle	1987	2,435,407	1,584,163	5,142.2	100.2	18.6
Clearwater	1987	1,668,573	987,971	3,197.7	65.6	14.6
Nez Perce	1980	2,223,993	911,669	4,575.8	25.9	6.0
North Idaho		6,327,973	3,483,803	12,915.7	191.7	39.2
Payette[3]	1986	2,323,145	795,980	2,156.0	25.0	8.3
Boise[4]	1990	2,647,908	1,317,941	2,739.7	19.8	9.0
Sawtooth[5]	1987	1,803,602	99,211	--	--	--
Challis[6]	1987	2,581,200	340,608	439.4	10.9	--
Salmon	1987	1,777,000	985,700	1,278.9	20.3	1.9
Caribou	1985	1,262,934	162,800	193.8	4.7	1.5
Targhee	1985	1,500,000	767,400	1,015.2	7.1	2.8
South Idaho		13,895,789	4,469,640	7,823.0	87.8	23.5
Total		20,223,762	7,953,443	20,738.7	279.5	62.7

Source: Individual forest plans for each forest, except as indicated by footnotes.

[1] Acreage has been confirmed by each national forest, and includes only federal acres within the state of Idaho.

[2] Gross Annual Growth less Annual Mortality = Net Annual Growth (see Glossary for precise definition).

[3] Payette National Forest data are from 1979 inventory data. More recent inventory data completed in 1991 are based on 431,721 suitable acres, with a total volume of 1,055 million cubic feet (MMCF), gross annual growth of 16 MMCF and annual mortality of 22.5 MMCF, for a net annual growth deficit of 6.5 MMCF.

[4] Boise National Forest data are those reported in the forest plan based on 1985 inventory data. The plan also reported inventory data for 1966 and 1976. It was the only Idaho national forest plan that reported inventory data as a time series. Annual growth and mortality data were reported in board feet and have been converted to cubic feet, using a factor of 4.1 board feet per cubic foot, derived from forest plan data.

[5] The Sawtooth National Forest plan identified an additional 141,429 acres as tentatively suited but not cost efficient for timber production. The plan did not report any growth, mortality, or growing stock volume information. A long-term sustainable yield of 22.6 million board feet per year (approximately 4.5 million cubic feet) is given, of which 8.9 million board feet are not cost efficient.

[6] The Challis National Forest plan reported gross annual growth, but no estimate of annual mortality was given.

Table 14-4. Idaho national forests: analysis of annual growth and mortality data.

		Per Acre Analysis			Percentage Analysis			
National Forest	Forest Plan Date	Growing Stock Volume	Net Annual Growth[1]	Annual Mor-tality	Mortality as % of Growing Stock Volume	Gross Growth as % of Growing Stock Volume	Net Growth as % of Growing Stock Volume	Mortality as % of Gross Growth
		(cubic feet per acre)			(percent)			
Panhandle	1987	3,246	63	12	0.36%	2.31%	1.95%	15.7%
Clearwater	1987	3,237	66	15	0.46%	2.51%	2.05%	18.2%
Nez Perce	1980	5,017	28	7	0.13%	0.70%	0.57%	18.8%
North Idaho		11,500	55	11	0.30%	1.79%	1.48%	17.0%
Payette[2]	1986	2,709	31	10	0.38%	1.54%	1.16%	24.9%
Boise[3]	1990	2,079	15	7	0.33%	1.05%	0.72%	31.3%
Sawtooth	1987	--	--	--	--	--	--	--
Challis[4]	1987	1,290	32	--	--	2.48%	2.48%	--
Salmon	1987	1,297	21	2	0.15%	1.74%	1.59%	8.6%
Caribou	1985	1,190	29	9	0.77%	3.20%	2.43%	24.2%
Targhee	1985	1,323	9	4	0.28%	0.98%	0.70%	28.3%
South Idaho		9,888	20	5	0.30%	1.42%	1.12%	21.1%
Total		21,388	35	8	0.30%	1.65%	1.35%	18.3%

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[1] Gross Annual Growth less Annual Mortality = Net Annual Growth (see Glossary for precise definition).

[2] Payette National Forest data are from 1979 inventory data. More recent inventory data completed in 1991 are based on 431,721 suitable acres, with a total volume of 1,055 million cubic feet (MMCF), gross annual growth of 16 MMCF and annual mortality of 22.5 MMCF, for a net annual growth deficit of 6.5 MMCF.

[3] Boise National Forest data are those reported in the forest plan based on 1985 inventory data. The plan also reported inventory data for 1966 and 1976. It was the only Idaho national forest plan that reported inventory data as a time series. Annual growth and mortality data were reported in board feet and have been converted to cubic feet.

[4] The Sawtooth National Forest plan did not report any growth, mortality, or growing stock volume information. The Challis National Forest plan reported gross annual growth, but no estimate of annual mortality was given.

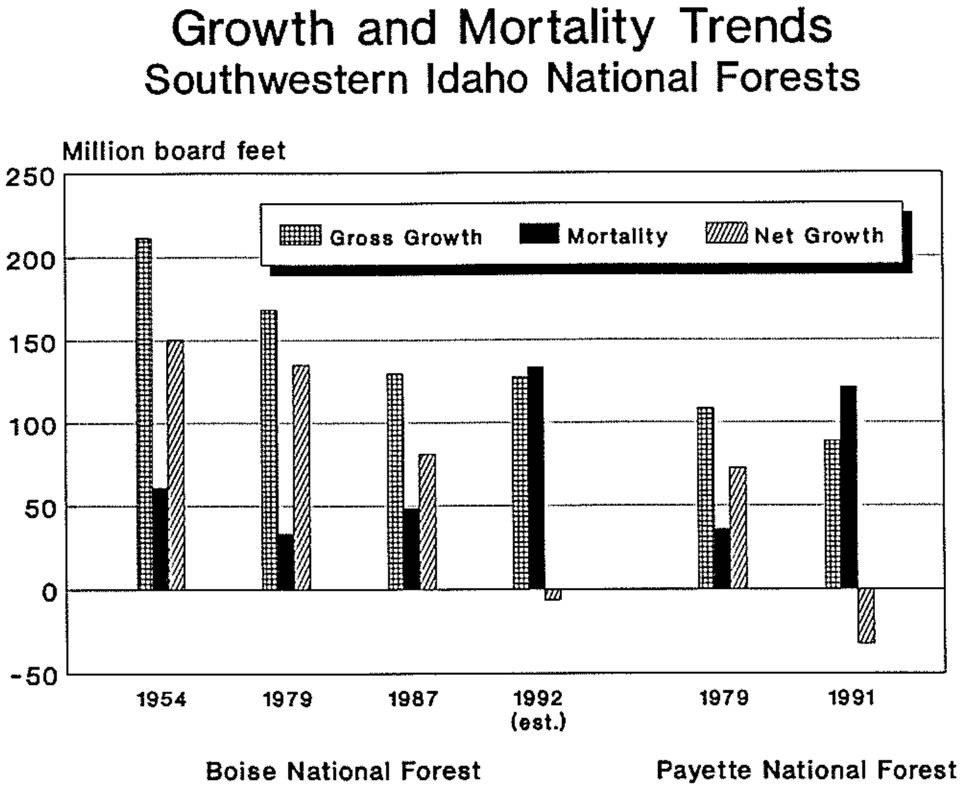


Figure 14-5. Timber annual growth and mortality trends in Idaho's Boise and Payette National Forests, 1954-1991. (Source: forest inventories, except Boise 1992 estimates).

1987.

Mortality for 1992 was estimated by Boise National Forest staff. Consistent with the method for stand examinations of mortality when an inventory is taken, estimates were made over a five-year period and then averaged for a 1992 estimate (see Table 14-5). Insect-caused mortality was estimated by relating airborne visual estimates with land-based data in a geographic information system and verifying the estimates on the ground (see Boise National Forest 1993). Fire-caused mortality was estimated by staff based on a variety of records. Efforts were made by staff to be conservative with their estimates. Even so, these estimates are crude approximations. The next scheduled inventory on the Boise is 1995, when more accurate growth and mortality data will be collected.

Boise National Forest mortality data for 1992 (Figure 14-5) indicate a situation that can be described as catastrophic, when mortality exceeds growth during a given period (McGuire 1958). Even without mortality estimates, significant growth reductions over time are evident in Figure 14-5. The decline in gross annual growth alone indicates forest decline on the Boise National Forest. Annual growth declined by 39%, from 211.8 million board feet in 1954 to 129.8 million board feet 1987.

Declines in gross annual growth may result from overstocked young stands or from an aging forest. Whether either situation is good or bad is a value judgment. Some may say an aging forest is bad because forest productivity, as measured by tree growth, declines as trees get older. Others may say it is good because the older a forest gets the closer it is to old-growth conditions. These data are for lands

Table 14-5. Timber mortality estimates, Boise National Forest, 1988-1992 (million board feet)

	Suited lands[1]	Unsuited lands
Insect-caused		
Bark beetles	82,805	21,877
Tussock moth	222,543	36,634
Total	305,348	58,511
Fire-caused		
1989 fires	194,000	126,000
1992 fires	167,700	168,300
Total	361,700	294,300
Grand Total	667,048[2]	352,811

[1] Suited lands are those identified in the forest plan as suitable for timber production.

[2] 55% of this volume was recovered in salvage sales (47% of insect-killed and 63% of fire-killed timber.)

Source: Boise National Forest staff

that have been identified in the forest planning process as suited for timber production. Growth reductions on those lands may represent a forest management problem, partly because 62% of the land base in the national forests in Idaho is excluded from timber harvesting according to the forest plans.

For the Payette National Forest, unpublished data from inventories of the forest completed in 1979 and 1991 are depicted in Figure 14-5. Gross annual growth on suitable timberlands on the Payette declined 18% when sawtimber is the measure, and as shown in Figure 14-5, the decline was 36% for all timber growing stock volume. Along with growth decline, mortality tripled from 1979 to 1991. As on the Boise in 1992, mortality on the Payette in 1991 exceeded gross annual growth. This net loss of growing stock volume (Figure 14-5) is even more significant when one considers that the inventoried land base identified as suitable for timber production has been reduced by 46%, from 795,980 acres in 1979 to 431,721 acres in 1991. The situation on suitable timberlands in the Payette National Forest also meets the definition of catastrophic mortality.

The analysis that follows uses the annual growth and mortality data already presented, but expressed in three ratios commonly used by the U.S. Forest Service to describe tree mortality: mortality per acre, mortality as a percent of growing stock volume, and mortality as a percent of gross annual growth.

Mortality per acre.—This is a common way to express mortality (Benson et al. 1987, USDA Forest Service 1990b). Figure 14-6(a) depicts timber mortality on a per acre basis for the four regions used in the analysis. A range from approximately 7 cubic feet per acre per year to upwards of 13 cubic feet per acre year is evident across the Inland Northwest and the United States. This range of mortality can be used to represent the expected range of variability in timber mortality per acre over large areas during the period 1952 to 1987. When mortality per acre is outside this range, a forest health problem may exist, as tree mortality would fall outside the range of expectations. A word of caution: this range is based on limited data representing one-third or less of the life cycle of a forest stand.

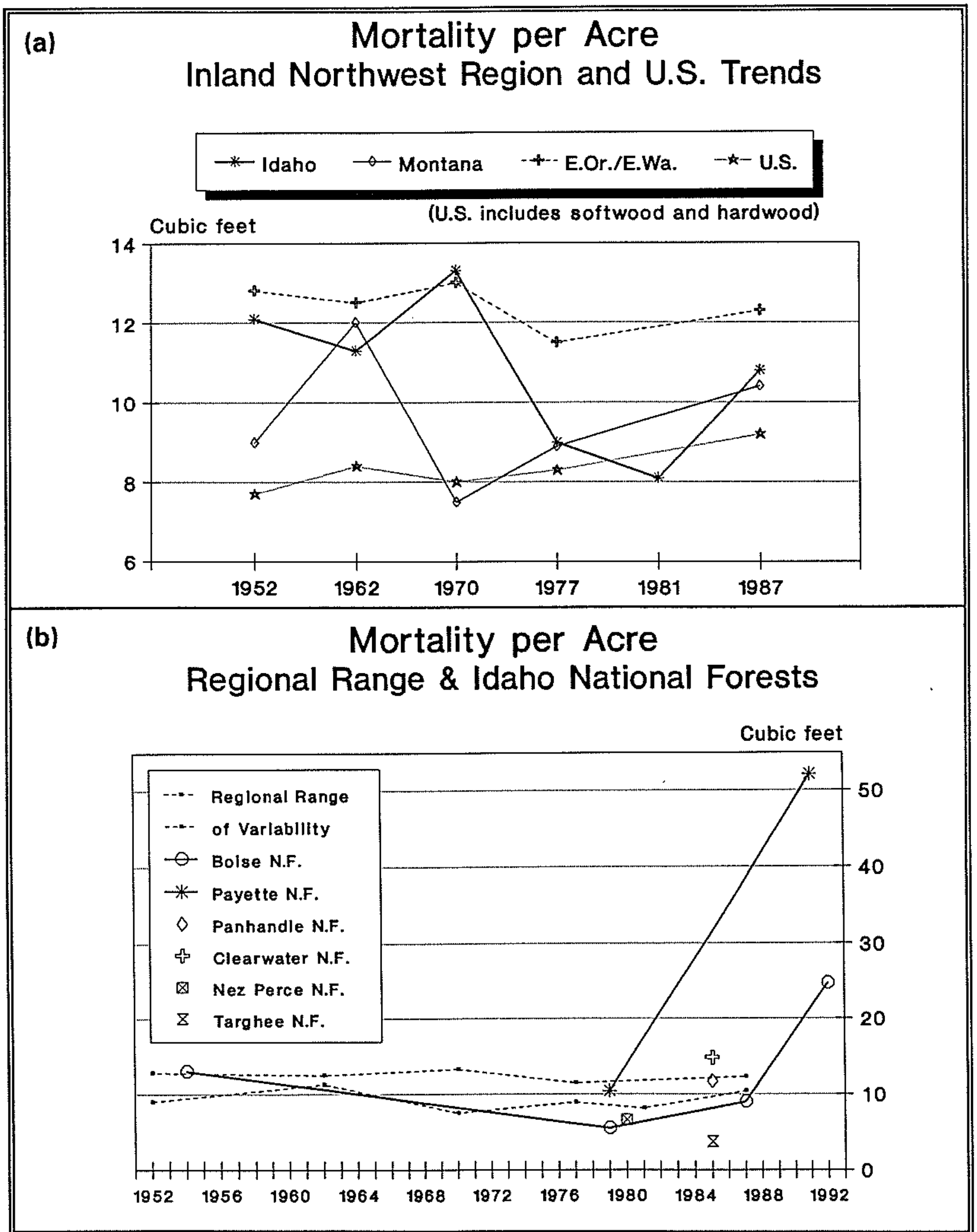


Figure 14-6. Timber mortality per acre trends: (a) in Idaho, Montana, and the eastern portions of Oregon and Washington, 1952-1987, with U.S. trend for comparison; (b) Inland Northwest regional range and selected Idaho national forests.

The range of variability within the region, as depicted in Figure 14-6(a), is used to determine if the mortality data for the Boise and Payette National Forests, depicted in Figure 14-5, lie outside this range. The lowest mortality rates in Figure 14-6(a) for 1952, 1962, and 1987 are for the entire United States. These data points were not used to define the regional range, which are the highest and lowest mortality rates for Idaho, Montana, or eastern Oregon and Washington for each time period. Also presented are the single data points for some of the other Idaho national forests (from Table 14-4). The results are illustrated in Figure 14-6(b). The Boise National Forest was at the upper limit of the regional range in 1954, but has fallen below it since then. Based on mortality per acre, the Boise did not appear to have an unusual situation until 1992, when estimates indicate twice the expected mortality. The Payette National Forest, with its high mortality rate in 1991, fell well outside the regional range of variability, having had four times the mortality that might be expected. Based on data presented in forest plans (Table 14-3 and 14-4) the Clearwater National Forest fell just above the regional range in 1985. Other national forests were within the range or below it. Inventory data for 1990 on the 3.5 million acres of forests outside the national forests in northern Idaho (Wilson and Van Hooser 1993), which represent 23% of all Idaho timberlands, show 13.7 cubic feet per acre of mortality. This is slightly above the upper limit of the regional range for 1987 as shown in Figure 14-6.

Mortality as a percentage of growing stock volume.—Using the same approach for this commonly used expression of mortality (USDA Forest Service 1990b, Filip and Schmitt 1990), the range of variability lies between .4 and .7 percent, as depicted in Figure 14-7(a). Overlaying the data from the Boise, Payette, and other Idaho National Forests, the result in Figure 14-7(b) illustrates roughly the same relationship as in Figure 14-6(b). The Boise National Forest was within the range until 1992, when mortality was twice what would be expected in the region. The Payette National Forest was within the range in 1979, but in 1991 mortality was almost four times above the range of variability. Other forests, based on the data reported in their forest plans, did not display anything unusual. However, based on analysis of permanent plots, national forests in northern Idaho are experiencing mortality of 3% to 4% in mature stands, with some plots as high as 10% (Hayes 1993, based on S. Hagle, pers. comm.). This level of mortality is even higher than the recent mortality data presented in Figure 14-7(b) for the Boise and Payette National Forests. Inventory data for 1990 on the 3.5 million acres of forests outside the national forests in northern Idaho (Wilson and Van Hooser 1993) show that annual mortality is 0.63% of the growing stock volume, just at the upper limit of the regional range for 1987 in Figure 14-7.

Mortality as a percentage of gross annual growth.—This is the measure suggested by the Society of American Foresters task force report on Sustaining Long-Term Forest Health and Productivity (Norris et al. 1993). It has been used by the U.S. Forest Service to describe Idaho forest resources (Benson et al. 1987) and by Filip and Schmitt (1990) to describe root disease mortality on true fir species.

Figure 14-8(a) shows that the range of variability in this measure of mortality was from 15% to almost 35% (for the Inland Northwest gross annual growth). The downward trend includes growth increases evident in Figure 14-4. Again, by overlaying this range of variability in the region with Idaho national forest data, the results in Figure 14-8(b) reveal that the Boise National Forest was within the regional range in 1954 and 1979, and outside it in 1987 and 1992. In 1987 this was less a function of high mortality than it was low growth, but in 1992 the combination of high mortality and low growth resulted in mortality slightly in excess of growth. The Payette National Forest was in the range of variability in 1979, and in 1991 was well beyond it, when mortality was 1.4 times gross growth on suitable timberlands. Mortality on the Targhee National Forest was

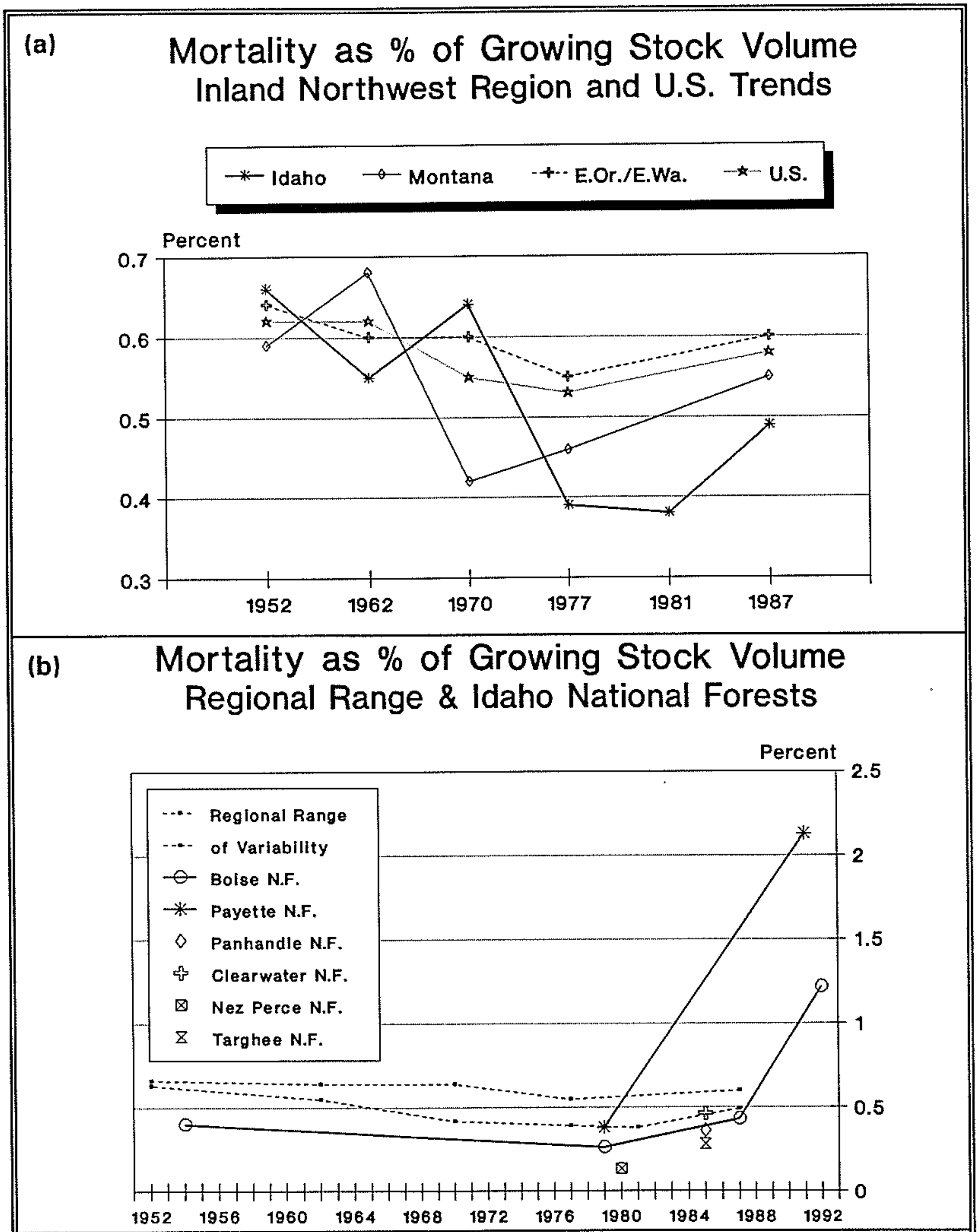
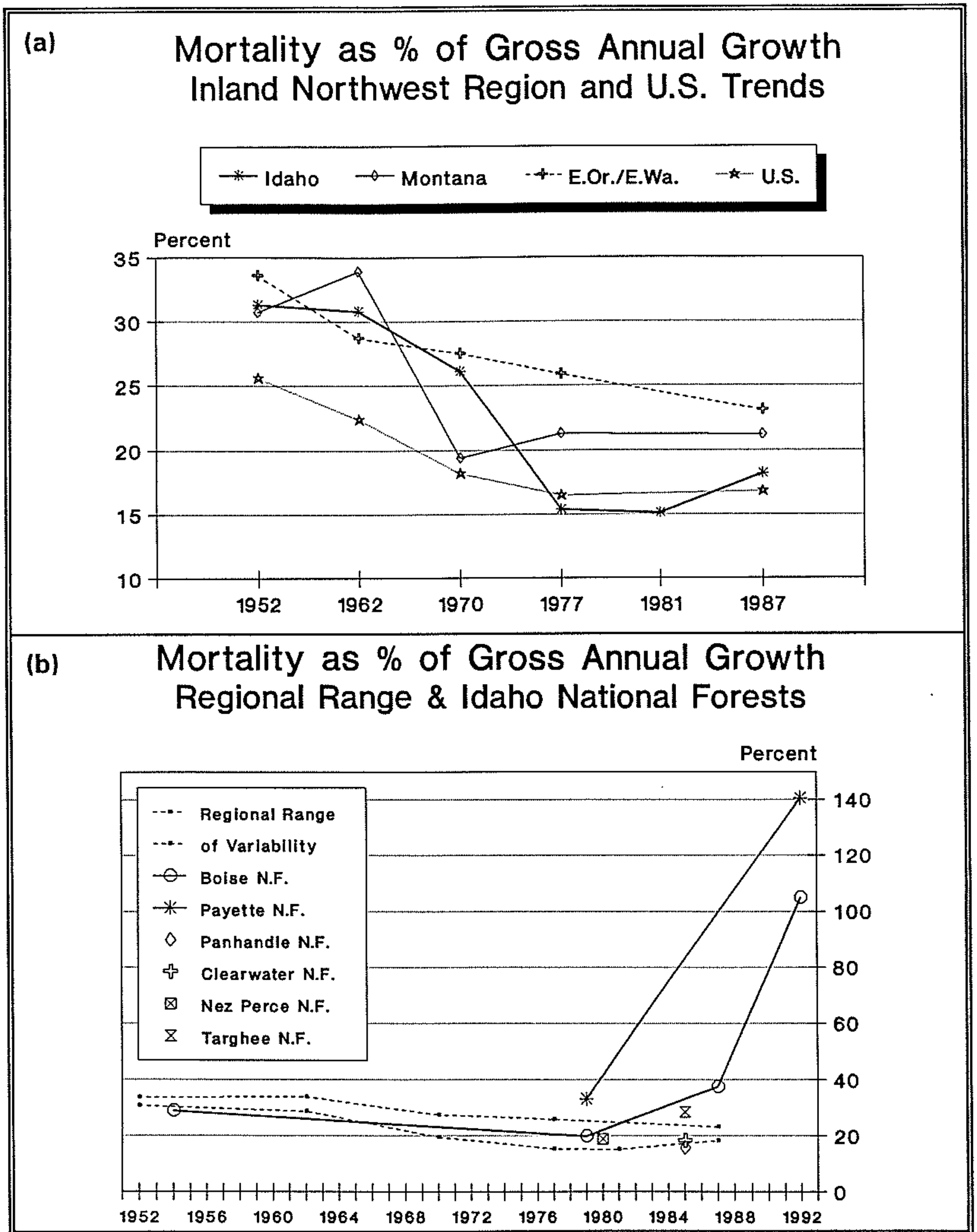


Figure 14-7. Timber mortality as a percentage of growing stock volume trends: (a) in Idaho, Montana, and the eastern portions of Oregon and Washington, 1952-1987, with U.S. trend for comparison; (b) Inland Northwest regional range and selected Idaho national forests.


(a) Mortality as % of Gross Annual Growth Inland Northwest Region and U.S. Trends

(b) Mortality as % of Gross Annual Growth Regional Range & Idaho National Forests

Figure 14-8. Timber mortality as a percentage of gross annual growth trends: (a) in Idaho, Montana, and the eastern portions of Oregon and Washington, 1952-1987, with U.S. trend for comparison; (b) Inland Northwest regional range and selected Idaho national forests.

28% of gross growth in 1985, slightly higher than the regional range. Although not depicted, the Caribou National Forest had mortality at 25% of gross growth in 1985, at the upper limit of the regional range. Inventory data for 1990 on the 3.5 million acres of forests outside national forests in northern Idaho (Wilson and Van Hooser 1993) show mortality as 17.1% of gross annual growth, well below the upper limit of the regional range for 1987 in Figure 14-8.

Is there a tree growth and mortality problem in Idaho? From the data that are available, tree mortality fell outside the regional range on the two national forests in southwestern Idaho (Figure 14-8b). Both the Boise and Payette National Forests have recently experienced levels of mortality that exceeded gross annual growth. The forests also have declining gross annual growth, thus contributing to an unfavorable relationship between growth and mortality. To the extent that tree growth and mortality data reflect forest health, it may be said that the Boise and Payette National Forests both have a forest health problem on lands suited for timber production. Analysis of current mortality data for some other Idaho forests also reveals symptoms of forest health problems (see the section before Conclusions).

Precipitation Trends

One of the principal reasons why mortality rates in southwestern Idaho might be higher in the 1990s than earlier is the prolonged drought in southern Idaho that began in 1986. What are the historic trends in precipitation during the fire season (May 5 to October 1) in various Idaho locations? How do annual precipitation trends compare? How do recent levels of precipitation compare with historic averages? There can be no doubt that drought creates a more stressful environment for trees, and some tree species are better adapted to drought than others. According to the *Forestry Handbook* (Hook et al. 1984):

> Drought may be defined as a lack of precipitation for a long enough period of time to cause depletion of soil moisture and injury to trees and other vegetation. The species of tree, the water-holding capacity of the soil, and the prevailing atmospheric conditions determine the length of time before a drought exists. Drought resistance or drought tolerance describes the ability of trees and other vegetation to survive drought conditions differentially. Some species of trees have adaptations that increase their tolerance of drought...[including] deep root systems that prolong the absorption of water.

However, drought is not the only factor affecting forest health. The downward trends in gross annual growth (Figure 14-5) document a forest condition possibly related to age class structure and other physical characteristics of forests. Unfortunately, data are not available to document how forest age classes and stand densities have changed throughout Idaho. Such data might also explain some of the downward trend in gross annual growth as experienced in the Boise and Payette National Forests (Figure 14-5). We will explore problems related to forest stand density on these two national forests as a case study in Chapter 16.

Data specific to Idaho on trends in precipitation, insect infestations, and forest fires were assembled to document conditions related to forest health. To facilitate this analysis, data were summarized by Bailey's (1980) natural ecoregions. Two forested ecoregions occur in Idaho: the Columbian Forest Ecoregion (north Idaho) dominated by cedar/hemlock/Douglas-fir climax communities and the Rocky Mountain Forest Ecoregion (south Idaho) dominated by grand fir/Douglas-fir climax communities (Figure 14-9).

Precipitation data from ten weather stations in the Columbia Forest Ecoregion and eleven in the Rocky Mountain Forest Ecoregion were obtained from the University of Idaho's Department of Agricultural Engineering. The location of the weather stations is illustrated in Figure 14-9. They were selected because they are within or near Idaho national forests and provide a reasonably adequate pattern of geographic coverage. Precipitation records began in the mid-1900s for 10 of the stations, and all stations consistently reported data from 1974-1991. Three measures of precipitation

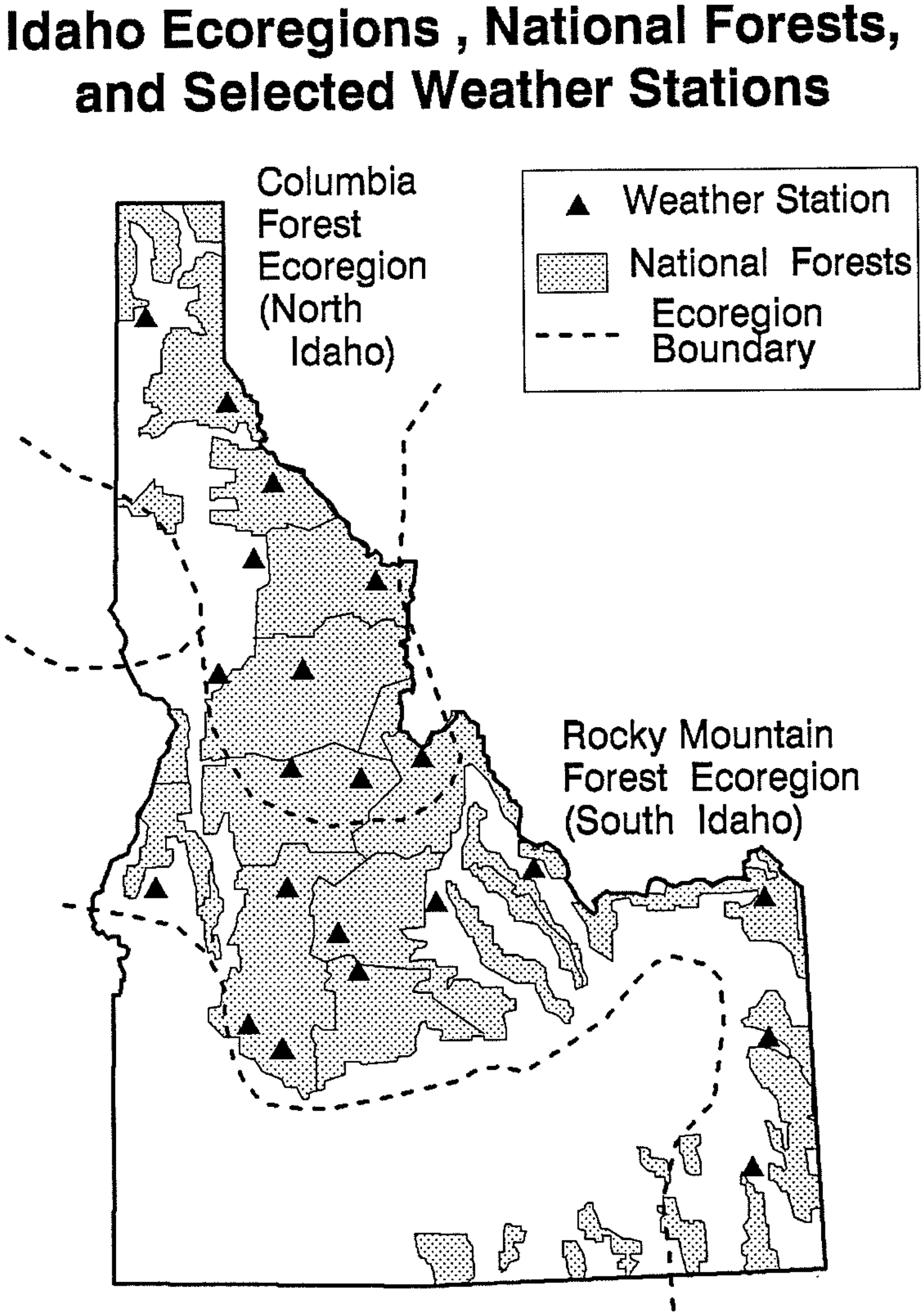


Figure 14-9. Idaho ecoregions, national forests, and selected weather stations.

were examined: annual total, fire season (May-October) total, and total cumulative snowpack. Because these data were highly variable from year to year, we used a 5-year moving average to smooth the data to facilitate analyses and comparisons. In addition, illustration of trends was portrayed better with smoothed data. Plots of the data (Figure 14-10) indicated a distinct difference in precipitation between the two ecoregions. Average annual precipitation for north Idaho in Figure 14-10(a) was 28 inches, and 18 inches for south Idaho as illustrated in Figure 14-10(b). Standard errors associated with these two means were 0.5 inches and 0.4 inches, respectively. Fire season averages were 9 inches for north Idaho and 6 inches for south Idaho, with standard errors of 0.2 inches. The recent drought was much more apparent in the south Idaho precipitation data.

In contrast to precipitation trends, snowpack records illustrated in Figure 14-11 were more equivocal between the two ecoregions. Total cumulative snowpack averaged 95 inches in north Idaho and 91 in south Idaho, with standard errors of 4 and 6 inches, respectively. In addition, the effects of the recent drought were apparent in the annual snowpack data for both ecoregions.

One earlier drought period is identifiable from the data in Figure 14-10. It occurred beginning in 1917 with the start of the records and lasted until the mid- to late-1930s, and was longer and more severe than the more recent drought, which fell well within the 95% confidence interval around each mean.

Visual Symptoms of Foliar Damage

Damaged trees are attributable to a number of causes, including insects, disease, and wildfire. What are the historic levels of forest fire, insect, and disease disturbance, and how do current conditions compare to them? That is, what might be considered baseline trends in fire, insects and disease? The scope of inquiry is limited in this case by availability of data.

Foliar damage from insects and disease in Idaho has been assessed annually since 1976, thus providing a 15-year record. Depending on the insect, data are available as numbers of trees affected, number of acres affected, or estimates of timber volume affected. For these purposes, number of acres is preferred for its comparability to fire occurrence, but this data is only available for bark beetles, not for defoliating insects.

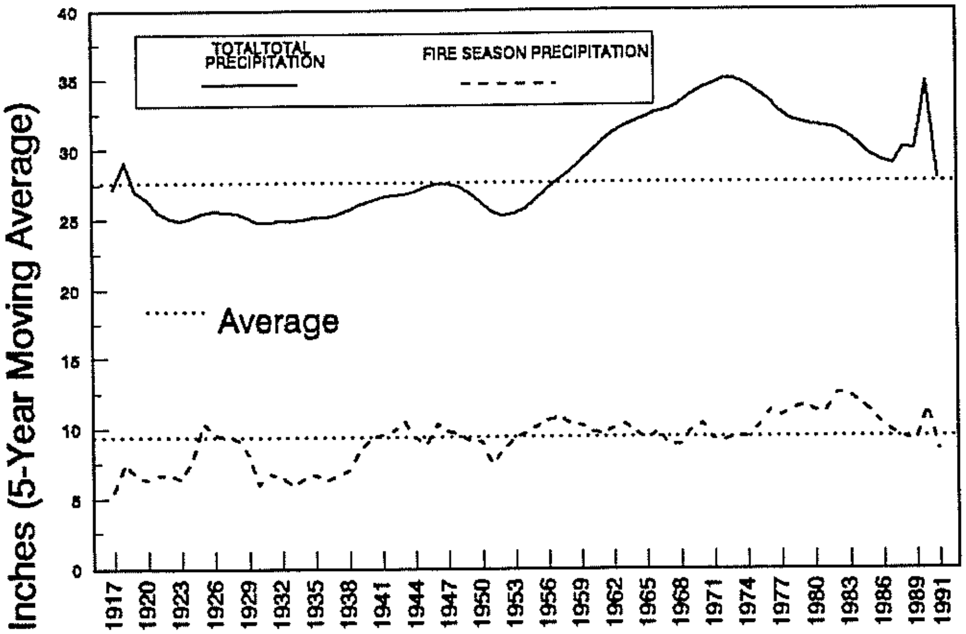
There are conceptual and perceptual problems using visual symptoms as forest health indicators, especially defoliators. Some insects defoliate trees, rather than kill them, and trees may recover from defoliation. Depending on the tree species, continued defoliation over three growing seasons will usually kill a tree. Gast et al. (1991) presented data indicating that in 1990 in the Blue Mountains national forests, 41% of all acres showed effects from western spruce budworm, a defoliator; another 12% of the forest area showed mortality from bark beetles; and the remaining 47% of the forests were unaffected.

Does this data from the Blue Mountains document a problem? That is a matter of perception, and to some extent depends on how many defoliated trees actually die. But even if defoliation does not result in mortality, it reduces tree growth. Gast et al. (1991) described this "deteriorating health" problem in these forests as "tragic." Brooks (1992) of the Association of Forest Service Employees for Environmental Ethics (AFSEEE), said the value most at risk from "dying forests" is timber production, and that "insect and disease outbreaks, fires, and tree death are all part of a natural cycle of life and death in wild forests." More to the point, AFSEEE said data documenting the extent of the "crisis" are difficult to interpret; specifically, "'acres infested' with insects are, in some cases, meaningless since they provide no measure of the severity of the problem. More in-depth analysis is needed to determine the true state of these forests." As discussed in Chapter 8, other environmental groups have also questioned whether or not dead or defoliated trees are a problem.

Insects and disease. Data representing forest insect activity were available from two

Idaho Precipitation, 1917-1991

(a) Columbia Forest Ecoregion (North Idaho)



(b) Rocky Mountain Forest Ecoregion (South Idaho)

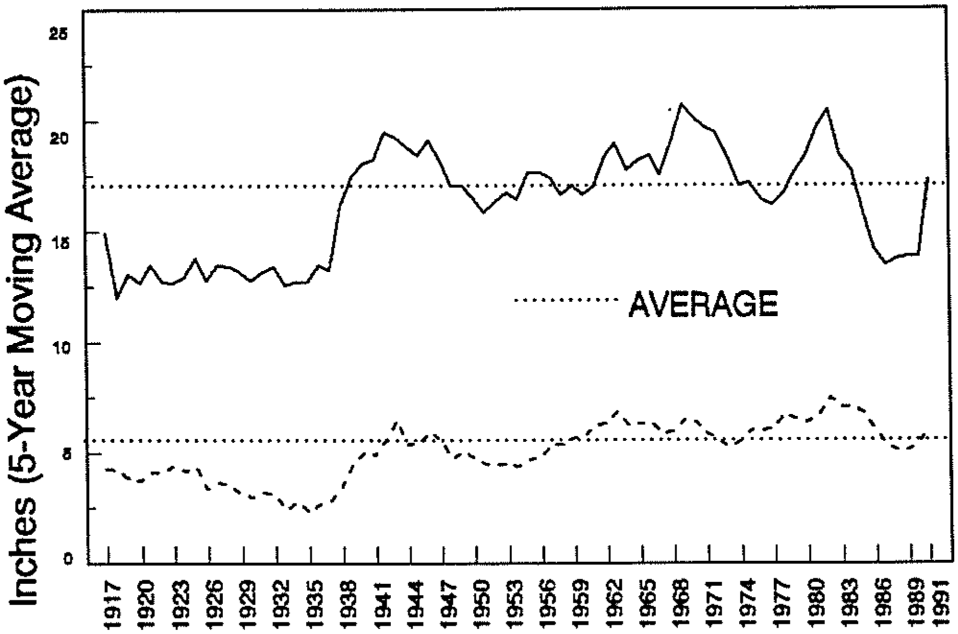


Figure 14-10. Idaho precipitation trends, 1917-1991; from (a) 10 weather stations in north Idaho (Columbia Forest Ecoregion) and (b) 11 in south Idaho (Rocky Mountain Forest Ecoregion).

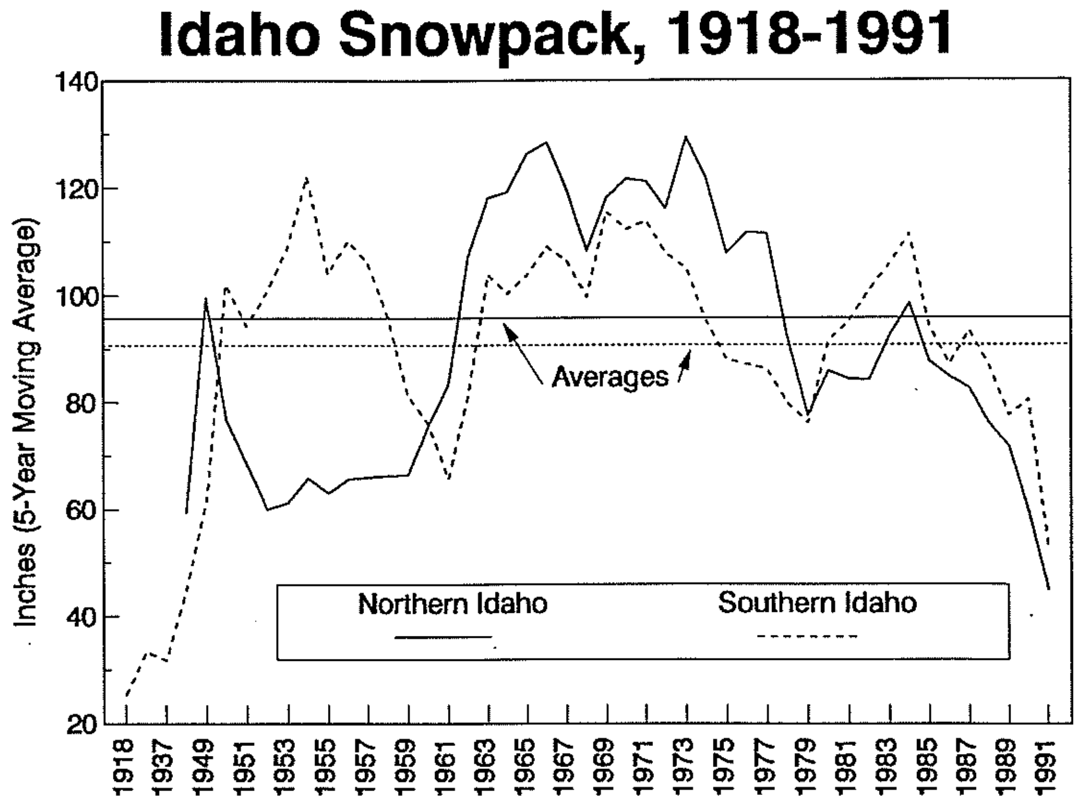


Figure 14-11. Idaho snowpack trends, 1918-1991.

sources. Disease activity is not as readily attainable or available. The Forest Insect and Disease Control project of the Idaho Department of Lands conducts state-wide aerial surveys each year. Data from this source were available from 1976-1991 (Idaho Department of Lands and USDA Forest Service 1991) and included national forests and surrounding lands. The second source of data was the U.S. Forest Service forest pest reports for Region 4. These data covered only the Region 4 forests in south Idaho, which we used primarily to confirm and supplement data collected by the Idaho Department of Lands. Both sources reported data as the number of trees killed by species of bark beetle, or acres of defoliated trees for species of *Lepidoptera*, primarily budworms and tussock moths. We summarized these data by lumping insect species into either bark beetle or defoliator categories and used a 5-year moving average to smooth the data.

When considered in the aggregate, in general, forest insect populations in north Idaho have existed at relatively low or endemic levels during the period of record (1976-1991), except for a rise in bark beetle activity (possibly epidemic) in the early 1980s (Figure 14-12). In contrast, insect activity has been greater, but more variable, in south Idaho. Trends were similar for both bark beetles and defoliators. Peaks in insect- related mortality and defoliation occurred around 1980 and again about 1984 (Figure 14-12). At the time we did the analysis, state-wide data beyond 1991 were not available. Available data indicated that previous defoliation in southern Idaho was due primarily to western spruce budworm, whereas the most recent events are due to Douglas-fir tussock moths (Idaho Department of Lands and USDA Forest Service 1991).

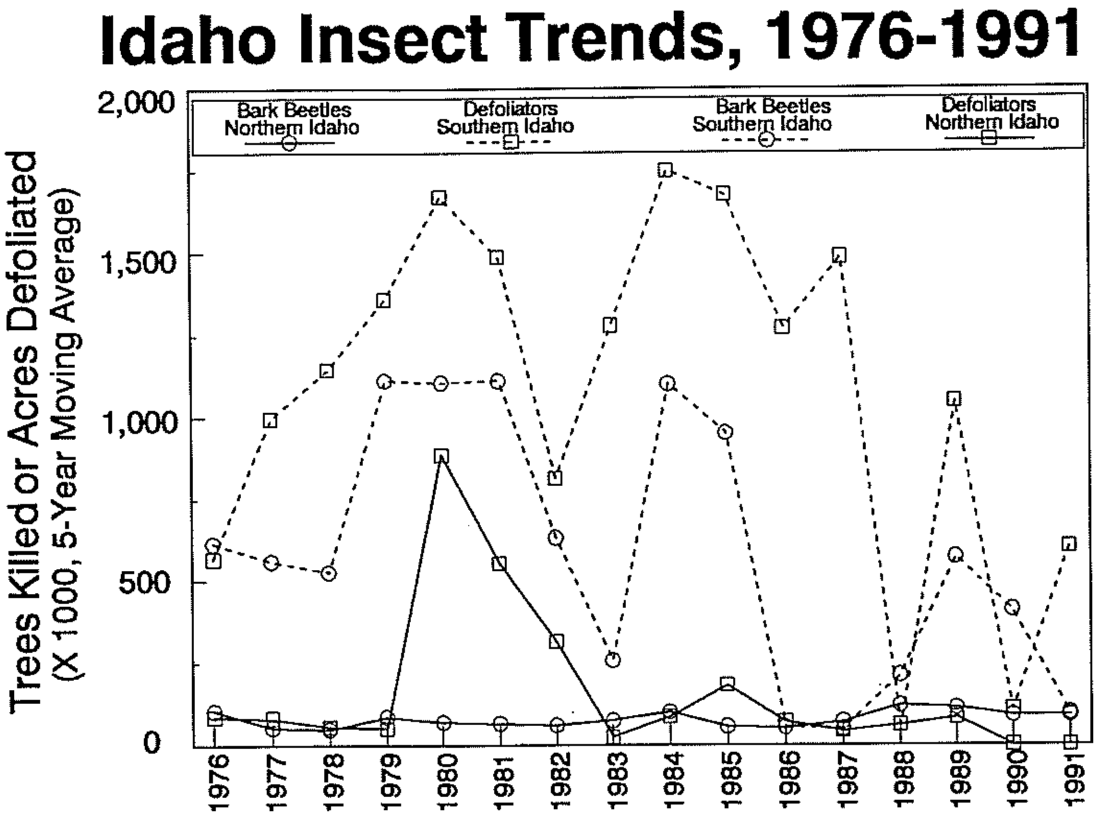


Figure 14-12. Idaho forest insect pest trends, 1976-1991.

Wildfire. Information on forest fires was requested from each national forest in Idaho. The data varied by forest, with some records beginning in 1921, and other forests supplying data only from the most recent 6 years. Data included number of fires and acres burned each year, often separated into man-caused and lightning strikes. We used acres burned due to lighting strikes, assuming that total acres burned each year would more accurately reflect environmental conditions brought about by relative moisture and fuel loads. Again, the data were highly variable from year to year, and we used a 5-year moving average to smooth the data. Trends in north and south Idaho in acres burned were similar except in the early years of the record (Figure 14-13). Recently, more acres have been burned in south Idaho than north Idaho, but both ecoregions have experienced a substantial increase in wildfire since 1984.

Relationships in the Data

The data on precipitation, insect activity, and wildfires indicated that forest health conditions are more problematic in the Rocky Mountain Forest Ecoregion (South Idaho) than the Columbia Forest Ecoregion (North Idaho). Coincidentally, the Blue Mountains of Oregon and Washington, where forest health issues have also been in the forefront, are also in Bailey's (1980) Rocky Mountain Forest Ecoregion. Because the tree mortality situation seems to cause more social concern in south Idaho, we focused on this ecoregion for these data summaries.

To make comparisons among these data, the means for precipitation, foliar damage, and wildfire were calculated using the entire

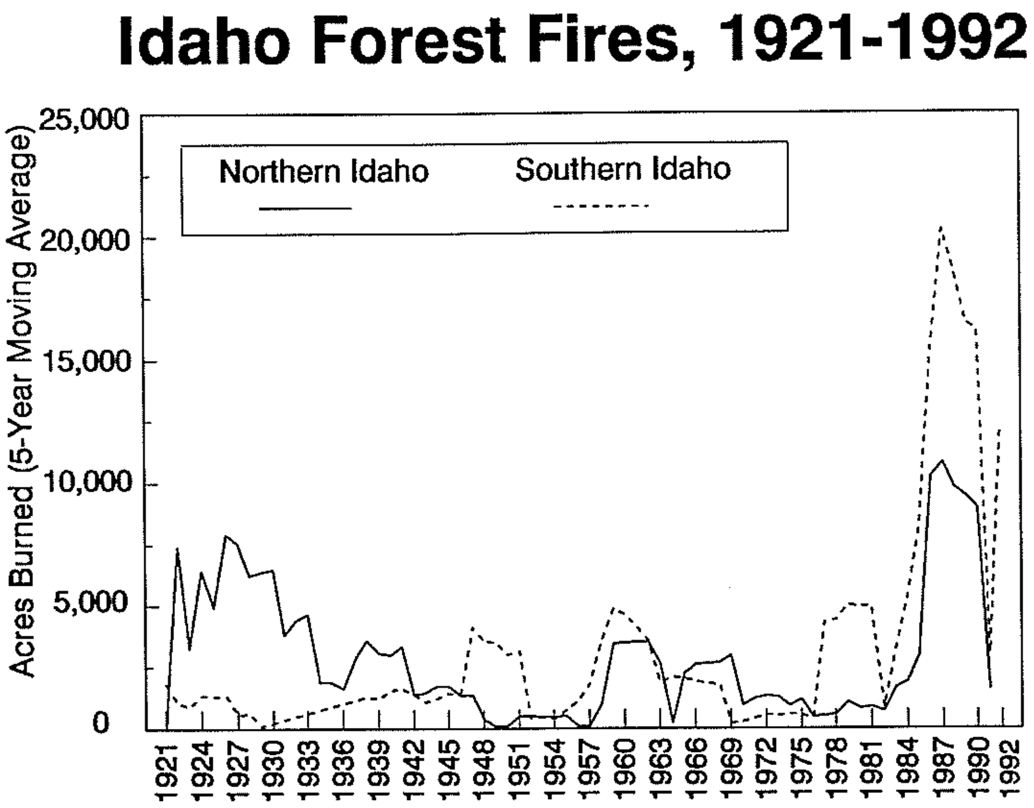
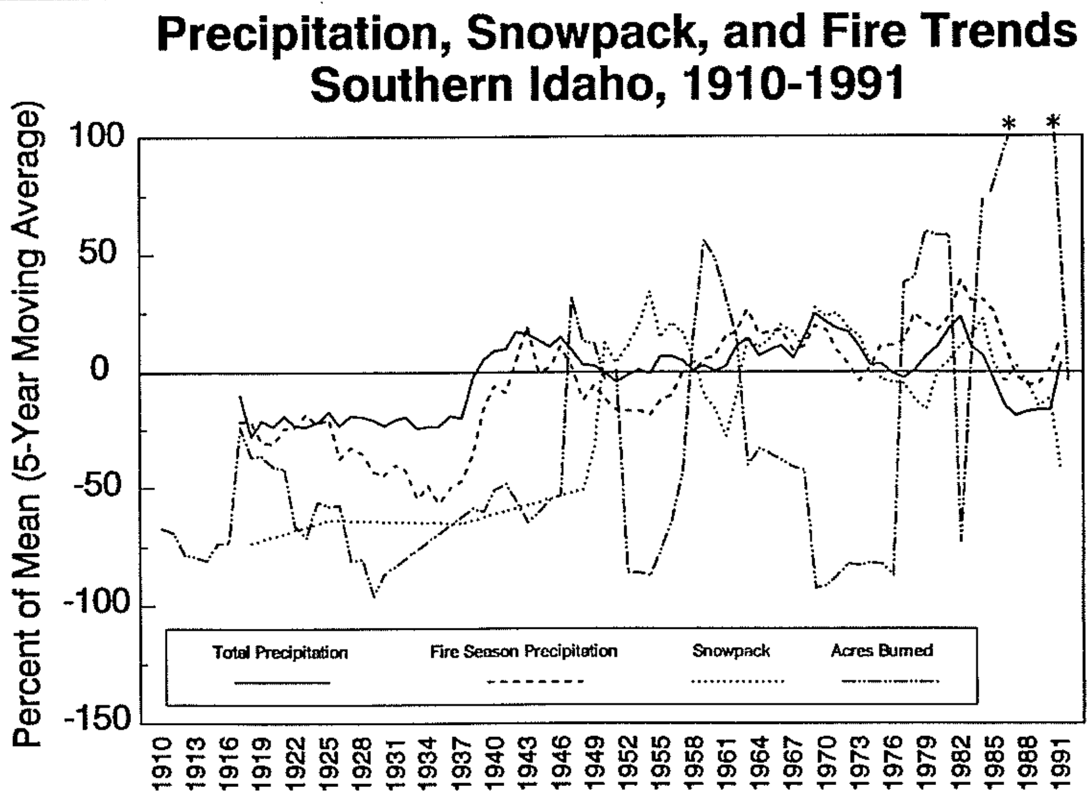


Figure 14-13. Idaho forest fire trends, 1921-1992.

unsmoothed record in each data set. Smoothed data points were then expressed as a percentage of that mean. The entire record for south Idaho for precipitation and wildfire is plotted in Figure 14-14. These same data are plotted from 1970-1991 in Figure 14-15(a), and are a better representation because earlier records were inconsistent for fire data. Insect data were added in Figure 14-15(b). It is difficult to visually determine any consistent pattern of relationships in the data. The statistical analysis that follows is somewhat more helpful.

It has been hypothesized that the following series of events contributed to current forest health conditions. In general, dense forest stands dominated by Douglas-fir and grand fir combined with drought made south Idaho forests susceptible to insect attack. Insect-caused mortality coupled with drought increased the potential for wildfire (Clark 1993c, McLean 1992, 1993). This hypothesized scenario was used to direct a statistical analysis of relationships among the data presented above. We would expect insect activity to be related to precipitation trends and wildfire occurrence to be related to precipitation and insect activity. We used linear regressions to evaluate associations among precipitation, wildfire, and insect trends. The smoothed data were used in these analyses, which should enhance the results by reducing the variation in the data.

Trends in tree mortality and defoliation due to insects were more closely related to total cumulative snowpack than to either total annual or fire season precipitation (Table 14-6). All of these relationships were positive, however , they were not strong, as indicated by r^2 values of less than 0.50. Analysis of



* Acres burned from 1986-1990 averaged more than 400% of mean.

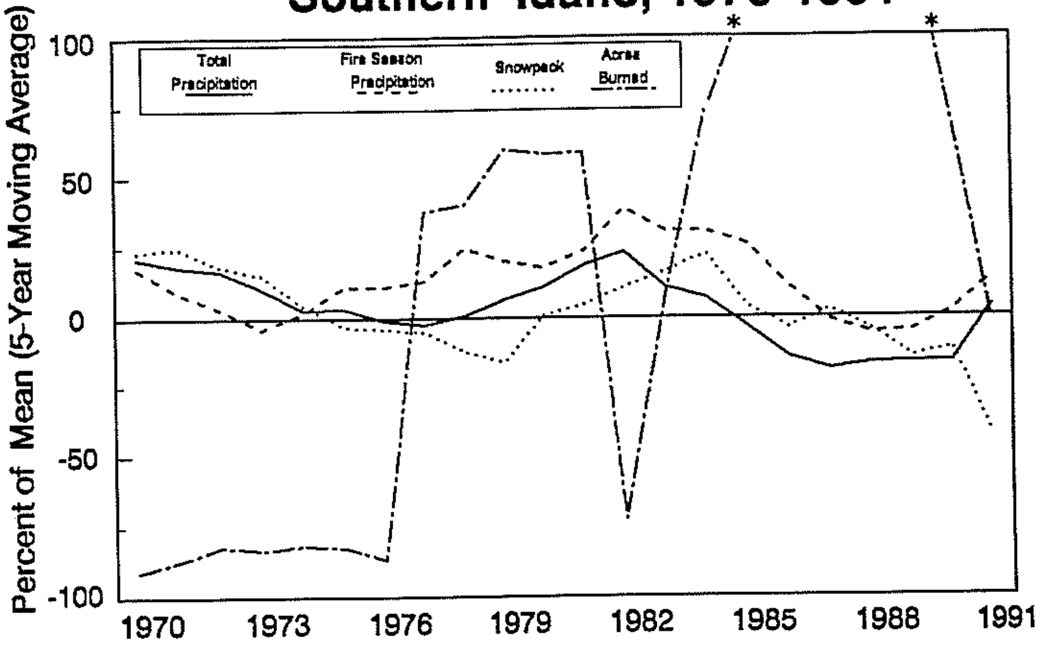
Figure 14-14. Southern Idaho precipitation, snowpack, and fire trends, 1910-1991.

these relationships using unsmoothed data would be expected to be even weaker. Weak relationships could be related to a number of factors including the aggregation of data over large areas instead of using matched data for specific sites where incidents of insect outbreaks or fires occurred.

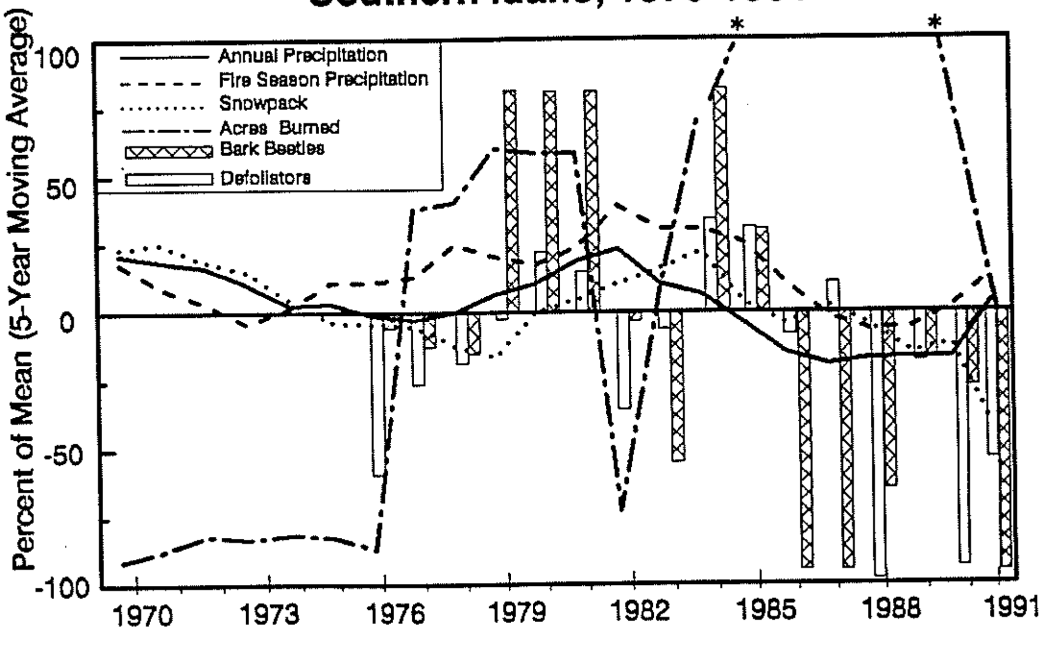
Trends in acres burned were inversely related to total annual and fire season precipitation when considered separately (Table 14-6). The relationship between acres burned and total annual precipitation than that between acres burned and fire season precipitation. The number of acres burned was strongly related to bark beetle-induced mortality, total annual precipitation and fire season precipitation when they were considered in combination (Table 14-6). The relationship of fire and precipitation might be even stronger if a 5 or 7 year time lag were built into the analysis.

The relationship between recent high tree mortality is difficult to explain with the precipitation, insect, and wildfire data analyzed in this section. Precipitation measures, particularly snowpack, were illustrative of the recent drought, but they also indicated that a more severe drought has occurred in the past. Data on forest fires, however, demonstrated a dramatic increase in acres burned from 1986-1990, with a return to average in 1991. Analysis of insect-caused tree mortality and defoliation as a result of precipitation levels was less illuminating. Growth and mortality data, as presented in the preceding section, seem to be more definitive.

(a) Precipitation, Snowpack, and Fire Trends
Southern Idaho, 1970-1991



(b) Precipitation, Snowpack, Insects, and Fire Trends
Southern Idaho, 1970-1991



* Acres burned from 1986-1990 averaged more than 400% of mean.

Figure 14-15. Southern Idaho trends, 1970-1991: (a) precipitation, snowpack, and fire; (b) same data plus insect mortality.

Table 14-6. Results of regression analyses for precipitation, wildfire, and tree mortality trends in southern Idaho.

Dependent Variable	Intercept	Slope	Independent Variable(s)	r^2	F-statistics
Bark beetles	20.5	0.49	Annual precipitation	0.05	
Bark beetles	22.4	1.06	Fire season precipitation	0.06	0.2 $P > 0.05$
Bark beetles	-10.8	0.5	Snowpack	0.45	0.1 $P > 0.05$
					13.4 $P = 0.01$
Defoliators	4.9	0.3	Annual precipitation	0.02	
Defoliators	-0.8	1.80	Fire season precipitation	0.06	0.6 $P > 0.05$
Defoliators	-6.1	0.2	Snowpack	0.49	1.9 $P > 0.05$
					15.4 $P = 0.01$
Acres burned	30275.5	-4292.4	Fire season precipitation	0.43	
Acres burned	30714.3	-1622.4	Annual precipitation	0.70	12.5 $P = 0.01$
Acres burned	6612.3	-30.8	Snowpack	0.07	36.8 $P = 0.001$
Acres burned	6584.9	-259.6	Defoliators	0.02	0.1 $P > 0.05$
Acres burned	447.5	-19.0	Bark beetles	0.07	0.7 $P > 0.05$
Acres burned	35918.4	33.4	Bark beetles, +	0.73	0.02 $P > 0.05$
		-1314.8	annual precipitation, +		14.7 $P = 0.01$
		-1829.6	fire season precipitation		

Does Idaho Have a Forest Health Problem?

According to Clark (1993c), most of the scientists at a forest health symposium in Boise, Idaho, in June 1993 agreed there is a forest health problem in Idaho. They commonly cited the underlying cause as the replacement of open forests dominated by fire-resistant tree species such as ponderosa pine and larch with dense forests dominated by fire-intolerant firs. In some Idaho forests, this change in forest composition has led to increased insect and disease activity, tree mortality higher than tree growth, severe wildfires, and changes in wildlife populations (Clark 1993c).

When do the response indicator criteria (foliar damage and tree growth efficiency) indicate the presence of a serious forest health problem? That is, when does a problem condition exist? For the analysis of visual symptoms of foliar damage, the available 15 years of data exhibited a wide range of variability, making it difficult to determine any consistent trends as a baseline. However, these data could be used to generate an appropriate confidence interval for defining a range of variability.

By analyzing existing tree growth and mortality data, a range of variability for mortality was defined. Using measurements of annual mortality in standard expressions related to acres, growing stock volume, or annual growth, it can be said that the Boise and Payette National Forests have exhibited symptoms of a problem. Both forests have higher than expected levels of mortality, in addition to growth decline, resulting in annual mortality in excess of annual growth. Our analysis of precipitation and other environmental trends does not fully explain what is happening in these forests. Forest age class or stand density structure are important factors we have not analyzed. We will explore the situation further by approaching these two national forests as a case study in Chapter 16.

The Bureau of Land Management has 3.8% of all Idaho timberlands. Approximately 387,225 acres of this (2.7% of Idaho timberlands) is located in southern Idaho. A recent inventory of BLM timberlands in southeastern Idaho revealed that 56% of the timber volume was "alive and healthy," 21% was infested with Douglas-fir bark beetle, and 23% was dead (USDI Bureau of Land Management 1992).

What about the forests in northern Idaho? Although the recent drought situation was not as serious in northern Idaho as in the southern part of the state (Figure 14-10), because of the prevalence of Douglas-fir and root disease, the long-term health of these forests is a cause for concern.

On the Idaho Panhandle and Clearwater National Forests in northern Idaho, permanent inventory plots have been used to assess root disease mortality and its causes and effects since 1985. Several thousand trees on hundreds of plots have been monitored. Mortality has been highest on grand fir and hemlock habitat types and lowest on Douglas-fir habitat types (see Byler et al. 1994, Hagle et al. 1992). According to Hayes (1993) and Hagle (pers. comm.) annual mortality averaged 3% to 4% of merchantable cubic foot volume in trees 80 years and older in the national forests in northern Idaho since 1985. On some plots annual mortality has varied from under 1% to more than 10%. Most mortality has been caused directly by root disease, especially in sawtimber size trees, or by stress attributed to root disease where the final cause of death was drought or insects. In comparison to Figure 14-7, which shows mortality as approximately 0.5% of growing stock volume, these data are much higher than those reported in the forest plans for these forests. However, these data do not represent the entire national forest. These plots were established after national forest plans were published in the mid-1980s.

According to Byler et al. (1994) root disease has reduced timber volumes in mature stands by 40 percent in some areas of the Coeur d'Alene River basin in the Idaho Panhandle National Forest. Hagle and Byler (1993) projected significant losses in productivity due to the combined effects of fire and root disease in the ponderosa pine forest type. Their results are presented in the next chapter to illustrate the ponderosa pine case study.

On private and other public forests in northern Idaho, recent timber resource inventory data do not show elevated levels of mortality in mature stands (Wilson and Van Hooser 1993). These two different sets of data were collected on permanent plots established for separate purposes. As Marsden et al. (1991) put it, the problem of reconciling the quality of pest data in timber resource inventories remains.

Conclusions

This analysis demonstrates that tree growth and mortality data can be used as a measure of forest health condition and can be compared to existing time series data. The existing data are for 35 years, which may not be long enough to be called an historic range. However, levels of mortality on national forests in southwestern Idaho are clearly at an elevated level—forests are dying faster than they are growing. Drought is partially responsible, but other factors—primarily species composition changes and dense stocking levels resulting from fire exclusion and past harvesting practices—have predisposed these forests to extreme effects of fire, insects, and disease. In northern Idaho, the prevalence of Douglas-fir and root diseases has been projected to have serious effects on long-term timber productivity. Existing inventories can be used to analyze forest conditions and document growth decline. Methods for acquiring new data on the causes of growth decline are worthy of attention by resource managers and researchers concerned about forest health. Immediate attention should be given to communicating forest health conditions to the public. The payoff will be a better understanding of forest health and collaborative efforts to design socially acceptable forest management strategies for protecting the long-term health and sustainability of our forests.

Major points from this chapter are as follows:

- Idaho forest tree species composition has changed. Ponderosa pine and western white pine were once the predominant species. Douglas-fir and grand fir are now the predominant species.
- Idaho forest volume increased by 12% between 1952 and 1987. Annual volume growth has been twice the annual timber harvest during that period.
- On the Boise and Payette National Forests in southwestern Idaho, the forests identified as suitable for timber production were dying faster than they were growing in the late 1980s and early 1990s. Neighboring private forests did not experience similarly high mortality rates (see Chapter 16).
- In northern Idaho, mature stands on the national forests are experiencing elevated levels of mortality from root disease. Inventories of private and other public lands do not indicate similarly elevated levels of mortality. The two different data sets involved are, however, not directly comparable. Some attention to improved forest health inventory information seems necessary.

In the remaining chapters, we will look at the current Idaho forest health situation first in terms of forest ecology in Chapter 15, and then as a management and policy case study in Chapter 16. In Chapter 17, we review management and research directions suggested in the literature and by this analysis.

PART IV. TOWARDS A FOREST HEALTH MANAGEMENT STRATEGY

Chapter 15. Forest Succession Case Examples

Forests in the Inland Northwest have changed considerably over the past 70 years. Two major forest species—ponderosa pine and western white pine—will be used to illustrate how these changes have come about and how forest health has been affected. As illustrated in Figure 14-3(b), forest growing stock volume has declined by almost 2 billion cubic feet from 1952 to 1987 for each of these species, and increased by like amounts for the firs. Fire exclusion and past timber harvesting practices in concert with successional processes have led to true fir and Douglas-fir becoming the most significant components of Idaho forests. Pest problems and the role of fire in these ecosystems are featured in this chapter.

The complex dynamics of forest ecosystems are illustrated. The key point is that agents of disturbance can keep an ecosystem from ever reaching its climax state. That is why Idaho once had vast forests of ponderosa pine and western white pine. Change is fundamental to all ecosystems. The term *forest succession* refers to the patterns of change in vegetation over time. Monnig and Byler (1992) pointed out that public understanding of the principle is often assumed by professionals, but that understanding may be lacking and may be at odds with the human desire to maintain stability and control the environment (Monnig and Byler 1992). This chapter will describe how some forests change.

As Monnig and Byler (1992) pointed out, the climax condition is popularly conceived as the goal to which forests are progressing. It is easy to envision it as the last and best forest, the forest primeval. However, it is not necessarily the natural state of forests in the Northern Rockies. Many forest types rarely reached climax conditions in pre-European times because of frequent disturbances. Forests developed under a second depiction of succession. Disturbances in forest succession were caused by insects, disease, and fire amplified by periodic drought. The interval between disturbances could range from a decade or less, to more than a century. Disturbance, however, was inevitable and had an important role in maintaining these forest types (Monnig and Byler 1992). Furthermore, insects and diseases play a natural role as regulators of forest ecosystems (Haack and Byler 1993).

Monnig and Byler (1992) said that the Northern Rockies have a large number of forest types because of the variety of site conditions in the region. A number of tree species are living at the edge of their ranges, and are susceptible to a variety of stresses. The two case examples in this section illustrate forest systems under stress. The ponderosa pine forest example illustrates how insects and diseases respond to subtle changes in forest species composition and structure. The example of the white pine forest demonstrates how the introduction of exotic pathogens affect the forest ecosystem. The case studies are brief, but serve to illustrate some of the major forces at work in Northern Rocky Mountain forest types, including insects, disease, and wildfire (Monnig and Byler 1992).

Wildfire is a major force in forest succession throughout the Northern Rocky Mountains. Lodgepole pine, for example, owes its present widespread occurrence to past fire. Without fire, Douglas-fir would dominate areas where ponderosa pine now occurs but is not climax. Similarly, periodic fire allows western larch and western white pine to persist on many sites where they are not climax. Fire also favors Engelmann spruce at the expense of subalpine fir (Wellner 1970).

Ponderosa Pine Forests

Many ponderosa pine forest stands have changed since the late 1800s. The number of trees has increased, and on some sites a change in the mix of tree species has occurred (Monnig and Byler 1992). Frequent surface fires historically played a major role in stand development, particularly through selectively killing fire-susceptible Douglas-fir and maintaining open stands of predominantly ponderosa pine. Fire control and selective harvesting of higher value pines have changed the course of forest succession on these sites. Open ponderosa pine stands have been converted to dense stands composed largely of Douglas-fir (Byler and Zimmer-Grove 1991).

The changes are attributable primarily to two factors: aggressive control of wildfire and timber harvest. Prior to European settlement wildfire generally occurred every five to fifteen years. These low-intensity fires typically consumed only the grass, brush, and small trees of the understory. Forestwide, the results were open, park-like stands of ponderosa pine (Monnig and Byler 1992).

When wildfire is controlled, vegetation develops vigorously under the mature trees. Sites tending toward dry may favor the development of an understory of young ponderosa pine. Wetter and cooler sites favor the development of shade-tolerant Douglas-fir in the understory. When the mature ponderosa pine are harvested, remaining immature Douglas-fir have a headstart in the development of a new forest. This avoids planting costs and the stigma of clearcutting because the site looks greener. Thus this practice has been widely implemented in some areas in the West (Monnig and Byler 1992).

A frequently mentioned impact is the increased risk of a high-intensity fire. A developed understory increases the likelihood that a fire will consume all the trees in the stand as the flames "ladder" from the understory to the forest canopy. The reservoir of fuels that once were consumed on a regular basis by low-intensity fires, now fuel a high-intensity canopy burn. After a high-intensity fire the site will return to an early stage of succession typically dominated by grass. On drier sites many years may pass before the trees return to the site. A second effect follows the replacement of ponderosa pine, a tree species that is relatively insect and disease resistant, with Douglas-fir, a species that is less resistant to pests on these dry sites (Monnig and Byler 1992).

Past management practices have put many stands at risk from western spruce budworm, root pathogens—especially Armillaria root disease—and Douglas-fir dwarf mistletoe (Byler and Zimmer-Grove 1991). The alternative to restoring these forests to a species mix more resembling the pre-European condition is a forest condition that is increasingly subject to insect and disease attack and catastrophic fire (Monnig and Byler 1992).

These descriptions of what has happened in the once-prevalent ponderosa pine forests of the West are complicated by the widespread distribution of ponderosa pine and the diversity of sites on which it has adapted. There are generally two ways to categorize ponderosa pine sites. The first is as the climax stage on warm, dry ponderosa pine habitat types. The second is as a seral stage on warm, dry Douglas-fir habitat types.

Fire adaptation. Because ponderosa pine is among the most fire-resistant of trees in the Inland Northwest, it has a competitive advantage over most other species when mixed stands burn. Ponderosa pine has many fire-resistant characteristics. Seedlings and saplings are often able to withstand fire. Seedlings and saplings can maintain themselves on sites with fire intervals as short as 6 years if fire severity is low. Thick insulative bark and the tendency for meristems (growth tissue) to be shielded by enclosing needles and thick bud scales contribute to the temperature resistance of pole-sized and larger trees (Fischer and Bradley 1987).

Ponderosa pine seedling establishment is favored when fire removes the forest floor litter and grass and exposes mineral soil. Fire resistance of the open, parklike stands is enhanced by generally light fuel loads. Heavy accumulations of litter at the base of trunks increase the intensity and duration of fire around some trees, often resulting in a fire scar or "cat face." Flammable resin deposits around wounds can make an individual tree susceptible to fire damage and can enlarge existing fire scars (Fischer and Bradley 1987).

Climax-stage type. The role of fire on this ponderosa pine type of site does not affect tree species, but will affect the successional stage and stand density. Propagation of fire into the crown of pole-sized and larger trees growing in relatively open stands on dry sites is unusual. First, the tendency of ponderosa pine to self-prune lower branches keeps the foliage separated from burning surface fuels. Second, the open, loosely arranged foliage does not lend itself to combustion or the propagation of flames. Third, the thick bark is relatively unburnable and does not easily carry fire up the bole or support residual burning. Resin accumulations, however, can make the bark more flammable (Fischer and Bradley 1987).

Seral-stage type. The situation on the seral-type ponderosa pine forest is more complex, because without periodic low-intensity thinning fires, ponderosa pine will disappear as these forests approach the theoretical Douglas-fir climax stage.

Role of fire.—In the Douglas-fir climax series habitat types, naturally occurring fire will maintain grasslands, open stands of Douglas-fir or seral ponderosa pine, and prepare seedbeds, as in the climax ponderosa pine type (Fisher and Bradley 1987). But there are additional effects (Davis et al. 1980):

> 1. Frequent fires in seral stands maintained a ponderosa pine "fire climax" condition by killing fire-susceptible Douglas-fir seedlings. In this role, fire frequency largely determined the stand composition.
>
> 2. Following a prolonged fire-free period, Douglas-fir regeneration became established beneath the canopy. A ground or surface fire that reached a thicket of saplings and small poles could ascend into the overstory, killing or injuring adjacent mature trees through the vegetative "fuel ladder." Fuel ladders increased the potential destructiveness of a fire by providing access to the canopy. During periods of high fire danger, this often resulted in a stand-destroying crown fire.

Historic fire frequency probably was not different from that of climax-stage ponderosa pine—usually 5 to 25 years between fires. Successful suppression of surface fires in open, fire-maintained stands over the last several decades has increased the potential for a fire to become severe (Fisher and Bradley 1987).

On moist ponderosa pine sites, Douglas-fir or grand fir often form dense understories, which may act as fuel ladders that can carry surface fires to the overstory. Consequently, crown fires are more frequent on moist sites than they are on dry sites. Understory ponderosa pine may also be more susceptible to fire damage because crowded conditions can result in slower diameter growth. Such trees do not develop their protective layer of insulative bark as early as do faster growing trees. They remain vulnerable to cambium damage from ground fires longer than their counterparts in open stands. The thick, overcrowded foliage of young stands or thickets also negates the fire-resisting characteristic of open, discontinuous crown foliage commonly found in this species (Fischer and Bradley 1987).

Successional pattern.—The theoretical climax forest is an all-aged or multistoried Douglas-fir forest, as shown in Figure 15-1 [subsequent bracketed numbers in this section refer to Figure 15-1]. Such a forest is unlikely to be achieved because of the prolonged fire-free period necessary for its development. Most old-growth forests will be open stands with varying understories depending on the stand's fire history. A grass/forb community with shrubs and conifer seedlings becomes established following a severe stand-destroying fire [No. 1]. Frequent fire during this stage can result in a fire-maintained grassland [No. 2]. A light burn during the herb/shrub stage may result in a seedbed favorable to conifer seedlings, but this may be unimportant where seedling establishment is not hindered by ground cover (Fischer and Bradley 1987).

In the absence of fire, the herb/shrub stage gives way to conifer seedlings. Except on those high-elevation sites above its cold limits, ponderosa pine will dominate initially if it dominated the prefire stand. Douglas-fir seedlings will also be present. Variation in seed crops is a factor in regeneration. A poor seed year often retards regeneration. A fire at this stage reverts the site to an herb/shrub state

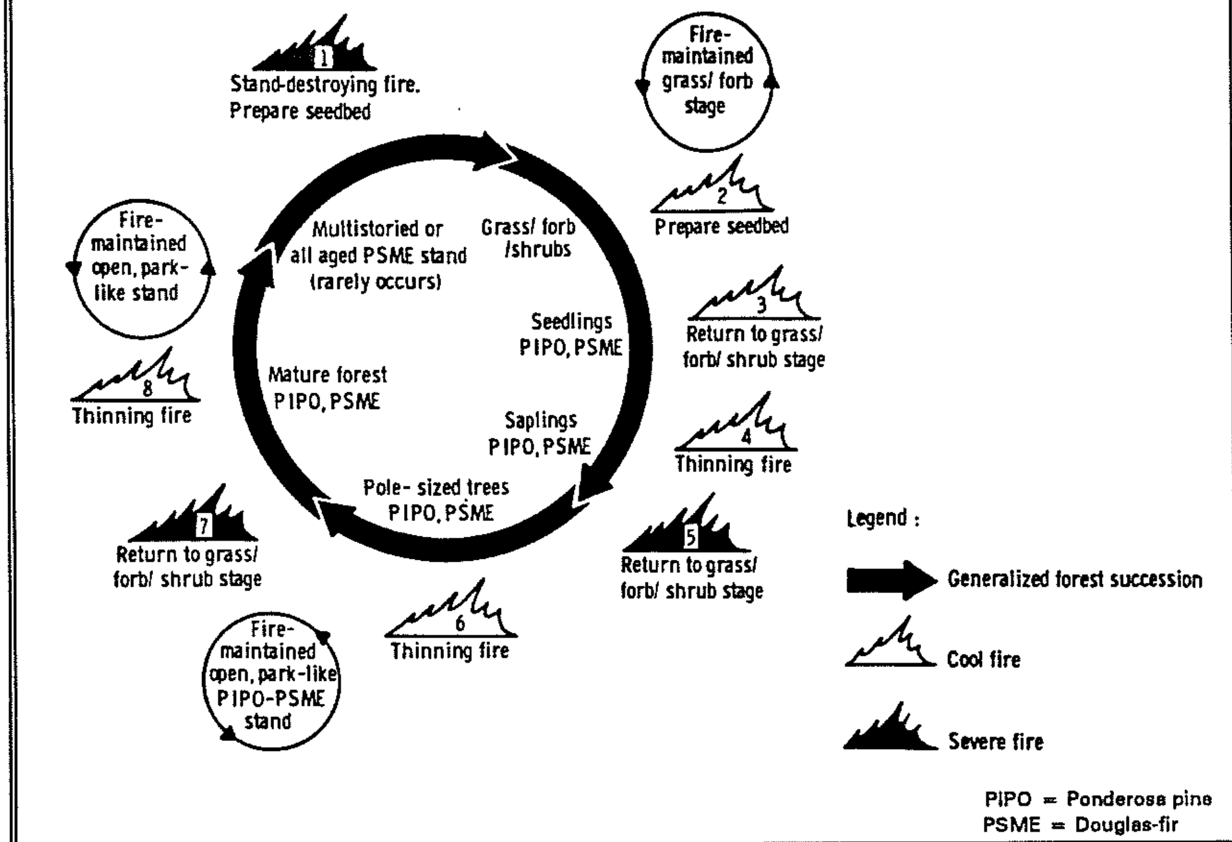


Figure 15-1. Generalized forest succession in warm, dry Douglas-fir habitat types.

Source: Fischer and Bradley (1987).

[No. 3]. In the absence of fire, ponderosa pine and Douglas-fir saplings develop. Species composition and density of stems depends on site conditions, length of the regeneration period, and how long fire has been absent. Not much ponderosa pine, for example, will be present if fire is absent for a prolonged period. A severe fire returns the site to the herb/shrub stage [No. 5]. A light to moderate severity fire tends to thin out Douglas-fir saplings and badly suppressed ponderosa pine saplings [No. 4]. A cool fire at this stage will also remove young seedlings (Fischer and Bradley 1987).

The pole-sized tree stage can be represented by [1] a rather open stand of Douglas-fir and ponderosa pine poles with a scattered seedling and sapling understory, [2] a predominantly ponderosa pine or Douglas-fir pole stand with varying understory, or [3] a scattered pole stand with grass/forb/shrub understory. A light to moderately severe fire at this stage may thin the stand, removing understory vegetation and susceptible Douglas-fir stems [No. 6]. Frequent fire maintains an open, parklike stand of ponderosa pine on most sites. A severe fire reverts the site to the herb/shrub state [No. 7]. A mature forest of ponderosa pine, Douglas-fir, or a combination of the two, will eventually develop. Periodic fire at this stage maintains the stand in an open, parklike condition [No. 8]. Douglas-fir and some ponderosa pine regeneration may form in the understory of such stands during fire-free intervals. If fire is excluded for an unusually long period, the theoretical climax situation could develop (Fischer and Bradley 1987).

Example of productivity loss. Preliminary modeling research results reported by Hagle and Byler (1993) indicate significant losses in future productivity in seral ponderosa pine forests in northern Idaho. (Seral refers to a biotic community that is in a developmental or transitional stage.) These projected losses, illustrated in Figure 15-5, result from the combined effects of fire exclusion, species conversion, and root disease.

The two fire regimes in Figure 15-2 are, first, a cycle of stand-replacing fires every 160 years (labelled "natural" fire cycle), with periodic low-intensity fires that favor ponderosa pine rather than Douglas-fir. This regime models "natural" fire frequencies and intensities. The second fire regime (labelled fire exclusion) is the end result of wildfire suppression. Seral ponderosa pine forests succeed to Douglas-fir without periodic low-intensity "thinning" fires. Douglas-fir is chronically affected by root disease in northern Idaho.

The difference in productivity is projected to be dramatic. Figure 15-2 illustrates modeling results from what happens to two types of hypothetical stands established in 1910, when severe wildfires swept through more than two million acres of forests in northern Idaho. In 1990, the stands in which periodic low intensity fires were allowed to burn have 12% more timber volume on them than the stands where fire was excluded. By the time 160 years has elapsed and another stand-replacing fire may be expected (in the year 2070), the difference in productivity is 43%. By the time two such cycles have run their course (in the year 2230), the productivity loss from fire exclusion is a staggering 92%.

The projections in Figure 15-2 are based on measurements taken in 10 ponderosa pine stands on Douglas-fir habitat type where fire has not been suppressed and 10 similar stands where fire has been excluded. These are preliminary results by Hagle and Byler (1993)

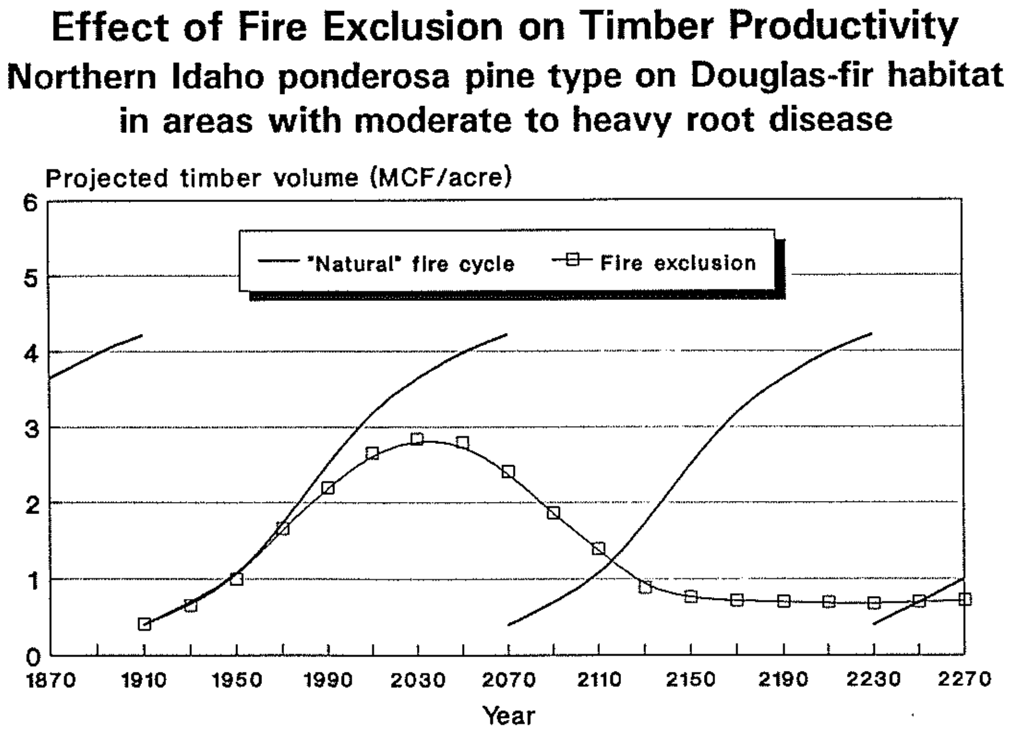


Figure 15-2. Effect of fire exclusion on timber productivity, northern Idaho ponderosa pine type on Douglas-fir habitat in areas with moderate to heavy root disease.

Source: Adapted from Hagle and Byler (1993).

using the Prognosis growth projection model (Stage 1973, Wykoff et al. 1982) and a variant for root disease effects (Stage et al. 1990).

Management strategy. According to Arno (1993), in fire-adapted ponderosa pine types, forest management practices in recent years have allowed fuels to build up to such an extent that ancient trees that survived many fires in past centuries are killed in modern fires. Because of fire exclusion and selective logging, modern wildfires may not restore the historic seral vegetation types, such as ponderosa pine. A strategy to maintain forest health will require that former ponderosa pine forests be managed to develop and perpetuate open stands of seral, fire-resistant pine and larch. This could be accomplished using restoration forestry involving a combination of silvicultural thinning in dense stagnating stands and prescribed burning to control the understory and allow regeneration of seral species (Arno 1993).

According to Mutch et al. (1993), a strategy to maintain forest health will require that seral ponderosa pine forests be managed for considerably lower tree densities. The desired density can differ depending on site productivity. Healthy forests will generally appear open and park-like. Forage production will be greatly increased and risk of catastrophic wildfire greatly decreased. To achieve this landscape, a combination of silvicultural partial cutting and prescribed fire will be needed. Stands that are now excessively dense and contain dead and dying trees will need salvage logging to remove unnatural accumulations of fuel (Mutch et al. 1993). The question will be how much partial cutting and prescribed fire will be necessary to promote healthy forest conditions, or avoid unhealthy conditions. The replies will be the subject of intense debate.

Western White Pine Forests

Western white pine was a major seral stage perpetuated in nearly pure stands by a 200-year fire frequency interval (McDonald 1993). These forests occurred on habitat types in which grand fir, western redcedar, and hemlock are climax. These forests today are much different than those that formerly occupied these sites. Pure and predominant white pine stands covered millions of acres in northern Idaho in the 1800s (Haig et al. 1941). It is estimated that western white pine was predominant on 35% to 40% of these types. Selective harvesting of high-value species and the devastation caused by the introduction of white pine blister rust reduced the white pine to about 4% of the type (Wellner 1984; A. Zack, pers. comm.). Douglas-fir, which formerly was "usually present, but seldom abundant" (Watt 1960) and grand fir, also susceptible to root disease, are predominant today.

In 1909 and 1910 white pine blister rust was introduced on contaminated nursery stock from Europe to the east and west coasts. In the west, blister rust has typically killed in excess of 90% of the western white pine. This has caused a major shift in species composition and ecosystem function (Monnig and Byler 1992; Byler et al., in press).

Our knowledge of the forest conditions of the late 1800s is incomplete. Stands of open, old-growth ponderosa pines covered the lower slopes. Mixed stands of subalpine fir and other conifers were present at high elevations. At mid-elevations vast areas were covered by stands of western white pine, usually mixed with western larch, grand fir and other conifers. Douglas-fir was often present, but seldom abundant. The extensive white pine forests were considered a major resource, and brought about a western migration of eastern sawmill owners (Monnig and Byler 1992).

Fire once maintained important forest characteristics. Periodic low-intensity fires burned through the white pine forests, killing understory Douglas-fir and other fire-susceptible tree species. Various diseases also were agents of change. Root disease fungi shifted species composition toward western white pine and western larch by selectively killing the more susceptible Douglas-fir and true firs. During the past century the white pine forests have endured many of the same human-induced changes that occurred in the ponderosa pine forest types. Fire control and selective cutting of high-value western white pine favored the more shade-tolerant Douglas-fir and true firs. Western white pine, when present, is seldom abundant. Blister rust fungus virtually eliminated reproduction of this key species from northern Idaho stands where it once was abundant (Monnig and Byler 1992).

Today, western white pine is nearly always a minor stand component. Douglas-fir and grand fir predominate in most stands. These species formerly were usually present, but seldom abundant, partly because of susceptibility to root disease. The most important cause of the shift to fir appears to be the introduction of the white pine blister rust fungus. This fungus eliminated most white pines from young stands that regenerated following wildfires and regeneration harvesting. Selective harvesting of high-value species contributed to the process, favoring grand fir and Douglas-fir (Byler and Zimmer-Grove 1991, Wellner 1984).

Root disease organisms also benefitted from these changes. In addition, beetles are common causes of Douglas-fir and grand fir mortality, particularly on trees weakened by root disease. The elimination of the overstory Douglas-fir and grand fir, and subsequent regeneration and death of these species on grand fir habitat types, results in what appears to be a self-perpetuating root disease center. Little timber volume accumulates, as these species are killed by root disease comparatively early, often at less than 100 years of age. The western white pine stage of succession is omitted. The timber resource has been greatly reduced, and watershed values have been affected as well (Byler and Zimmer-Grove 1991).

Thus, the inadvertent introduction of white pine blister rust had a major, devastating effect. It limited the growth of western white pine on these sites. The long-term solution is to regenerate disease-prone sites with disease-tolerant species. Rust-resistant western white pine is a key component of that solution in northern Idaho, where the species historically occurred in abundance, often in pure stands (Byler and Zimmer-Grove 1991).

Fire adaptation. Western white pine is moderately resistant to fire. Its resistance is enhanced by medium thick bark, moderately flammable foliage, self-pruning of lower limbs, and especially, its tall stature. But, older trees retain abundant resin in their bark and often have lichen-covered branches. These factors, plus the often dense stand structure, reduce western white pine's fire resistance (Fischer and Bradley 1987).

Young trees are especially vulnerable because of their compact stand structure and the lack of thickened bark. Western white pine is a fire species that depends on severe fires to recycle stands and create an early successional habitat. Its common occurrence in nearly pure, even-aged stands is further evidence of colonization after fire. Soil temperature and adequate moisture appear to control germination, but light seems to have little importance because seeds can germinate in shade. Mineral surfaces provide a better seedbed than duff surfaces, but white pine seed is able to maintain its viability in duff for 2 or 3 years then germinate upon the removal of the litter layer (Fischer and Bradley 1987).

The early growth of western white pine seedlings is not rapid, but it is the fastest growing sapling and pole-sized tree in the Northern Rockies. The first 30 to 40 years are critical to the development of the stand because during this time dominance and stand composition are established. Mortality and pruning subsequently determine the fire resistance of the stand and of individual trees (Fischer and Bradley 1987).

Western white pine is moderately shade tolerant and will continue to reproduce under a partial canopy of associated seral species (Douglas-fir, western larch, lodgepole pine, and perhaps grand fir). This ability and its longevity (400 to 500 years) permit it to remain as a stand component for several centuries following major disturbance (Fischer and Bradley 1987).

The historic role of fire appears more complex and is less well documented on habitat types in which the grand fir, cedar, and hemlock are climax than in the Douglas-fir series discussed above (Arno and Davis 1980, Marshall 1928). Nevertheless, it is clear that the forests of today are much different than those that formerly occupied these sites. Pure and predominant white pine stands covered millions of acres in northern Idaho in the 1880s. A generalized forest successional model can be constructed based on the literature (Byler and Zimmer-Grove 1991):

[1] The establishment of a mixed species stand following a stand replacement fire;

[2] The early elimination of Douglas-fir to root disease, and larch, lodgepole pine, and other species due to suppression; and

[3] The continuation of a pure or nearly pure white pine forest from about age 150-250 years, when increasing mountain pine beetle mortality again set the stage for a stand replacement fire.

Successional pattern. The theoretical climax condition is a reproducing stand of grand fir, western hemlock, or western redcedar, as shown in Figure 15-3 [subsequent bracketed numbers in this section refer to Figure 15-3] (Fischer and Bradley 1987).

Following a stand-replacing fire, succession begins with a shrub/herb field. Duration of this stage depends on the availability of tree seed and the occurrence of multiple burns [No. 1]. Many sites in northern Idaho initially burned in 1910, and subsequently reburned in the 1920s and 1930s, remain as shrub/herb fields today (Fischer and Bradley 1987).

If seed is available and multiple burns do not occur, seedlings of both climax and seral trees will establish on a burned site [No. 2]. Most fires occurring in the seedling/sapling stage will revert the stand to a treeless condition [No. 3]. Moisture is not generally limiting in these stands. These sites are highly productive, and pole and mature stands are usually dense. Although this condition leads to high fuel loading, severe fires are infrequent because of the high moisture status (Fischer and Bradley 1987).

Low to moderate fires [No. 4] in pole-sized or mature stands favor intolerant seral species over climax western redcedar, grand fir, or western hemlock, which are less fire resistant. When severe fires do occur in these stands [No. 5] they are generally returned to a shrub/herb field. This may be a short-lived condition if lodgepole pine was present in the preburn stand. In this case, seedlings of lodgepole pine would soon initiate a new stand. Mature larch may survive severe fires in mature or near-climax stands [No. 6]. These trees would then provide seed for a postburn stand. A "larch relict" stand may be the result of frequent low to moderate fires in mature stands (Fischer and Bradley 1987).

True climax status—where grand fir, western hemlock, western redcedar, or a combination are the only trees on site—is rarely achieved. Seral species are long-lived, and fire occurs frequently enough that stands seldom develop beyond the near-climax stage. Climax stands may withstand low thinning fires [No. 7], but moderate or severe fires [No. 8] return the site to a shrub/herb stage (Fischer and Bradley 1987).

Management strategy. One major forest health situation in the West—white pine blister rust—was caused by accidental introduction of a forest pest. A major effect has been species conversion, which can be reversed by aggressive management. If such management is not instituted, a new forest condition based on a 100-year fire interval is likely. If western white pine had been available to replant clear-cuts, most north Idaho stands would not be exhibiting forest health problems today, from conversion to Douglas-fir and grandfir (McDonald 1993).

Restoring these ecosystems will require intensive effort. It is fortunate that western white pine shows a low level of natural resistance to blister rust. Selective breeding programs by the Inland Empire Tree Improvement Cooperative, headquartered at the University of Idaho, have increased the rate of resistance among new nursery stock (Monnig and Byler 1992).

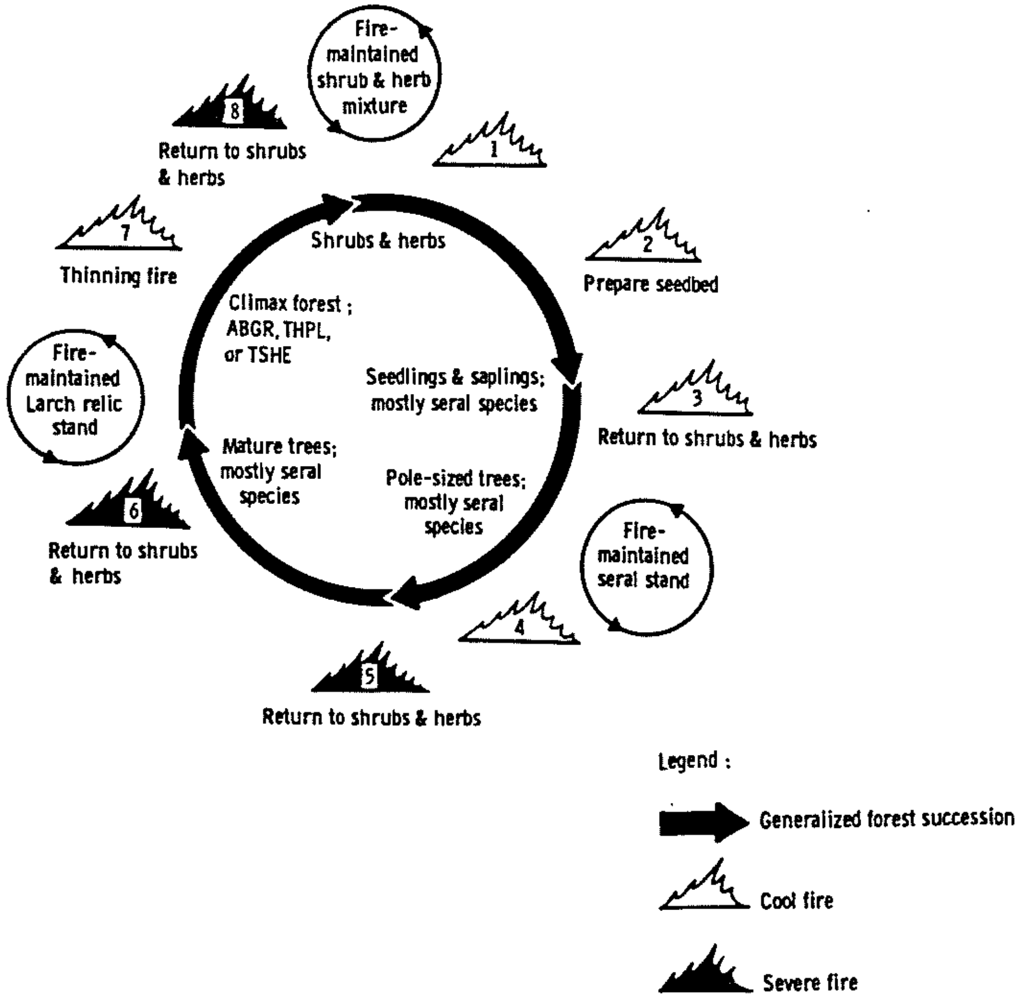


Figure 15-3. Generalized forest succession in warm grand fir, western redcedar, and western hemlock habitat types.

Source: Fischer and Bradley (1987).

Pest Problems

Because forest types have changed through human activities of fire suppression and timber harvesting, some former pine sites are nowoccupied by Douglas-fir and grand fir. Pines were more resistant to certain pests, so we are now witnessing pest outbreaks that were perhaps unprecedented before European settlement. The following sub-sections describe some of the pest agents that affect Douglas-fir and true firs, often referred to as host species for these organisms.

Western spruce budworm. Fire control and selective harvesting have put many stands at risk from western spruce budworm and contributed to the increased duration and intensity of outbreaks by creating more favorable budworm habitat (Schmidt 1985). Budworm feeds primarily on the foliage of Douglas-fir and true fir trees. Defoliation is most severe on trees growing in stressed conditions. Thus, the conversion of these stands to Douglas-fir and grand fir has increased the availability of food for the budworm. In addition, because the more shade tolerant Douglas-fir and grand fir are better able to regenerate under the canopy than ponderosa pine, a multi-storied stand develops with host beneath host. With increasing canopy closure, the stresses of the site increase. This adds to the availability of appropriate food. The multiple canopy layers also provide refugia from predation, parasitism, adverse weather conditions, and increases the number of landing sites for budworm larvae during dispersal (Schmidt 1985).

In the warm, dry Douglas-fir forests, low mineralization rates and frequent ground fires in the past have caused conditions of low soil nutrient availability (Stoszek 1988). Drought and the tie-up of nutrients in above-ground plant mass lowers nutrient availability in the rooting zone.

Budworm can rapidly expand from relatively rare status to that of a major pest (Schmidt 1985). During the decade from 1947 to 1957 aerially detectable budworm defoliation in western North America increased from a little over half a million acres to nearly 8 million acres and increased to almost 11 million acres by 1983 (Schmidt 1985). Human-induced changes in forest structure may cause shifts in budworm outbreaks (Swetnam and Lynch 1993).

***Armillaria* root disease.** Douglas-fir and grand fir are considered to be highly susceptible to root disease caused by Armillaria species (Entry et al. 1992). Conversion of ponderosa pine forests to these more shade-tolerant and disease-prone species has also helped to increase the incidence of damage from Armillaria root disease throughout the Interior West (Hadfield 1984, Wargo and Shaw 1985, Byler and Zimmer-Grove 1991). Altering species composition to include a greater proportion of disease-resistant species is the primary approach to managing this root disease.

Other management practices may be related to the degree of root disease infection. Practices creating stumps that ultimately serve as food bases for the fungi also favor Armillaria, so thinning and partial-cut harvests may extend the damage (Filip and Schmitt 1990). Also, practices that reduce soil fertility may cause increased root disease as well as insect damage.

Tree nutrition status is known to be related to the degree of host infection. Nutrient-deficient seedlings, for example, are more vulnerable to Armillaria attack (Singh 1983). Potassium is the primary constituent in resins that allow trees to defend against insects and diseases. Since about half of the potassium budget is concentrated in the leaves and fine branches (J. Moore, pers. comm.), it is a reasonable assumption that some slash disposal practices may cause reduction in the resistance to Armillaria as well as other agents.

Evidence indicates that the incidence of this root disease may be correlated with sites in the Douglas-fir habitat type series on which surface fires have maintained predominantly seral species. The only economical, long-lasting solution to Armillaria root disease in interior mixed conifer stands is by regeneration to disease-tolerant species (Byler and Zimmer-Grove 1991).

Douglas-fir dwarf mistletoe. Wildfire reduction, some forms of partial cutting, and the aging of infected stands have facilitated the spread of dwarf mistletoe. Practices that have created regeneration of host species beneath infected overstories have perpetuated the problem. The primary management action is to remove infected species and regenerate to non-host species (Filip and Schmitt 1990). Other viable management techniques include the removal of infected trees and removal of infected overstory trees after regeneration has been established (L. Livingston, review comments).

Douglas-fir tussock moth. The Douglas-fir tussock moth periodically causes serious timber mortality and growth loss in the region's forests. Large-scale outbreaks and damage were first recognized in the 1930s (Balch 1932). Although a part of the natural ecosystem, the tussock moth was apparently of minor importance. As reported by Dewey and Campbell (1978), Brubaker evaluated increment cores from more than 300 sites and suggested that severe attacks by the tussock moth may have been "rare events in the history of western coniferous forests." However, ongoing dendrochronology (tree ring) studies may challenge the traditional thinking of tussock moth outbreaks as rare events by establishing cyclic patterns, as Swetnam and Lynch (1993) have done for western spruce budworm.

The three principal host species are Douglas-fir, grand fir, and white fir (Stark 1978). In northern Idaho, stands dominated by mature and overmature grand fir are susceptible to tussock moth defoliation (Dewey and Campbell 1978). Overstocked, multistoried stands are most susceptible. Stoszek and others concluded that susceptibility to tussock moth increases as the ratio of stand density to site productivity increases (Stoszek 1978).

Past forest management practices have sometimes resulted in a substantial increase in stand susceptibility to defoliation by the tussock moth. As with other insect pests, the selective logging of old-growth ponderosa pine and exclusion of fire, speeding the transition of stands on dry sites toward fir, is an important factor (Dewey and Campbell 1978).

Conclusions

Conditions favoring the two most historically important forest tree species in Idaho have changed. Traditional notions of forest succession are that forests advance to a self-perpetuating climax stage. However, the two forest ecosystems described in this chapter seldom achieved the climax stage because fire played a major role that kept these ecosystems in a middle or seral stage, allowing ponderosa pine and western white pine to persist for long periods of time as a dominant species on the site. On many sites formerly occupied by ponderosa pine, Douglas-fir is now the dominant tree species. Two factors are responsible for the change: timber harvest and fire exclusion, or the aggressive control of wildfire. Many of these stands are at risk from several pathogens, including western spruce budworm and root disease, which also increases the risk of catastrophic wildfire. The long-term solution is species conversion and reduced stand density. Sites with Douglas-fir can be converted back to ponderosa pine, and stocking levels can be controlled by selective cutting. In some cases, prescribed fire may also be beneficial.

Western white pine now occupies less than 10% of its historic range. Like ponderosa pine, it is a favored timber species. White pine blister rust, an exotic disease that arrived in the Northwest in the early 1900s, has been a major factor inhibiting the reestablishment of western white pine following timber harvest. Fire exclusion has favored the development of shade-tolerant Douglas-fir and grand fir. Root disease organisms, prevalent throughout northern Idaho, lead to reduced timber resources as the susceptible Douglas-fir succumbs. The long-term solution is to identify disease-prone sites and regenerate them to disease-tolerant species. Rust-resistant western white pine is a key part of the solution. Western larch also can play a role.

It is evident that because fire has been excluded from sites formerly occupied by ponderosa pine, and western white pine, other ecological processes are now allowed to play their role. Insects and diseases on many sites are killing the Douglas-firs that have taken over. The result is fewer large trees, less timber volume, and increased fuel loads as young trees succumb to insects and disease. Management actions to control species composition and density would help avoid these unhealthy conditions.

Chapter 16. Management Policy Case Study in Southwestern Idaho

Forest health conditions on the two national forests in southwestern Idaho—the Boise and the Payette—were such that annual mortality exceeded annual growth in the late 1980s and early 1990s (see Chapter 14). Such a situation was defined by McGuire (1958) as catastrophic timber mortality.

Thousands of trees killed by defoliating insects, bark beetles and wildfire created this situation. Dead trees lose economic value rapidly. The best way to capture as much of the economic value as possible is to implement salvage logging operations as soon as possible. In recent years salvage sales largely replaced green timber sales on the Boise and Payette National Forests. Other cultural treatments, including the thinning of overstocked stands and slash removal, were combined with the salvage of dead material to enhance the health of the forest and to reduce the risk of costly wild fire.

The salvage of dead material and the application of cultural treatments, were opposed by some environmental groups. These groups have interpreted the salvage sale programs as "business as usual" for the Forest Service, and just another scheme to "get the cut out."

The Wallowa-Whitman National Forest—in Oregon's Blue Mountains just west of the Idaho border—has planned extensive salvage logging sales. In 1992, salvage volume was supposed to comprise from 50% to 90% of the timber program, declining as the fiscal year proceeded. However, those sales were appealed, resulting in 87% of the volume planned for sale being withdrawn or delayed because the administrative appeals were upheld. Many of those trees will not be harvested. Salvage sales on the Payette National Forest have been appealed. To avoid appeals, the Boise National Forest requested an exemption of salvage sales from the administrative appeals process, and the regional forester approved the request. According to McLean (1993), in 1992 and 1993, 95% of the timber volume sold on the Boise National Forest was salvage timber; 80% of it was logged by helicopter. Current plans are such that salvage logging will decline to 30% in 1994 and 10% in 1996. This course of action, although deemed necessary as part of the management strategy to restore forest health by forest products companies and the Boise National Forest supervisor, was opposed by environmentalists. These groups have interpreted the salvage sale program and accompanying exemption from appeals as "business as usual" for the Forest Service, and just another scheme to "get the cut out." These criticisms, detailed in Chapter 8, have been extended to the entire forest health strategy of the Boise National Forest (1992a) by those who distrust the motives and the abilities of resource managers to change the current situation. Salvage efforts on the Boise National Forest are under litigation as this is being written in late 1993.

In contrast, Boise Cascade lands lying between the two national forests offer a sharp contrast to adjoining national forest lands, with minimal losses due to insect attack. The sharp contrast between these lands appears to stem from the company's long-term emphasis on stocking control, the removal of trees at risk of insect attack, and the prompt salvage of mortality in these managed stands. These actions result in a younger age class structure than on the neighboring national forests, subjecting managers to criticism due to the lack of an old-growth component and other factors.

Changes in ecosystems, whether caused by human activity or not, complicate traditional multiple-use sustained-yield resource management. Ecosystem management will have to recognize that unanticipated and unplanned changes will occur and be flexible enough to adapt to those changes. The current situation in southwestern Idaho and the Blue Mountains provides a good example. The forest plans for these areas did not anticipate the unusually high tree mortality from recent outbreaks of insects, and therefore made no provisions for dealing with the situation.

This chapter describes some of the recent forest conditions on the Payette and Boise

National Forests—and Boise Cascade Corporation lands in southwestern Idaho lying between them—and the strategies used in addressing the salvage of dead and dying material and other efforts to confront forestry problems. Problems encountered in implementing these approaches are described and some suggestions for resource managers facing similar forest health problems are presented. Information was obtained from USDA Forest Service documents, other published sources, and through independent interviews with at least three representatives from each of the three organizations during the summer of 1992.

Description of Land Areas

Figure 16-1 is a map of the land areas in southwestern Idaho managed by the three organizations featured in this case study. In some areas Boise Cascade lands are intermingled with national forest lands.

The Payette National Forest includes approximately 2.4 million acres. Almost 33% of these lands lie within wilderness areas. Of the remaining land, 135,900 acres are non-forested, and 530,900 acres are not physically suited for timber production, leaving 821,000 acres (or 34% of the land base) of tentatively suited forest land under the 1986 Forest Plan. The average annual allowable timber sale quantity for the Payette was initially projected at 80.9 million board feet based on the intensive management of 431,100 acres of suited lands (Payette National Forest 1986). The inventory of the forest completed in 1991 was conducted only on these 431,000 acres (18% of the lands in the forest) because the remaining tentatively suited lands have effectively been removed from timber production through agreements with affected interest groups. Those lands may be added back to the suited base without a plan amendment if economic conditions change.

The Boise National Forest includes 2.65 million acres (USDA Forest Service 1992b). Two wilderness areas are located partly within the Boise's proclaimed boundaries, and account for 665,492 acres. The Boise also has 38 roadless areas totaling 1,209,000 acres. A projected annual allowable sale quantity of 85 million board feet is based on 656,114 acres of the Boise's 1,317,941 acres of lands identified as suitable for timber production (Boise National Forest 1990).

Boise Cascade Corporation owns 195,000 acres in southwestern Idaho in the vicinity of the two national forests (Figure 16-1). Forest types include 125,000 acres of grand fir or wetter habitat types and 70,000 acres of the drier Douglas-fir habitat types. The company did not wish to release information on timber volume. The tree species by volume on Boise Cascade timberlands are Douglas-fir (30%), grand fir (30%), ponderosa pine (30%), and smaller quantities of lodgepole pine, subalpine fir, and western larch (10%).

It is not possible from national forest inventory data to similarly identify species composition. For example, the Payette National Forest uses a mixed conifer category that characterizes 66% of the suitable timberlands. By definition, 75% of the trees in a mixed conifer forest type are ponderosa pine, Douglas-fir, grand fir, or western larch. There are 3 subdivisions of mixed conifer based on productivity class; 18% of the suitable timberlands are high-site mixed conifer, 43% are medium-site, and 5% are low-site. Further subdivisions of productivity classes are the seven strata representing stand condition. The remaining 34% of the Payette's suitable timberlands are predominantly Engelmann spruce (6%), subalpine fir (6%), lodgepole pine (6%), and seedling/sapling/poletimber stands, clearcuts, and burned or undifferentiated areas (16%).

Tree Mortality

Outbreaks of western spruce budworm, mountain pine beetle, western pine beetle, Douglas-fir beetle, spruce beetle, Douglas-fir tussock moth, and fir engraver have all occurred in southern Idaho over the past decade on both public and private forest land. A capsule summary of insect outbreaks over the last decade on the Payette and Boise National Forests is provided in this chapter.

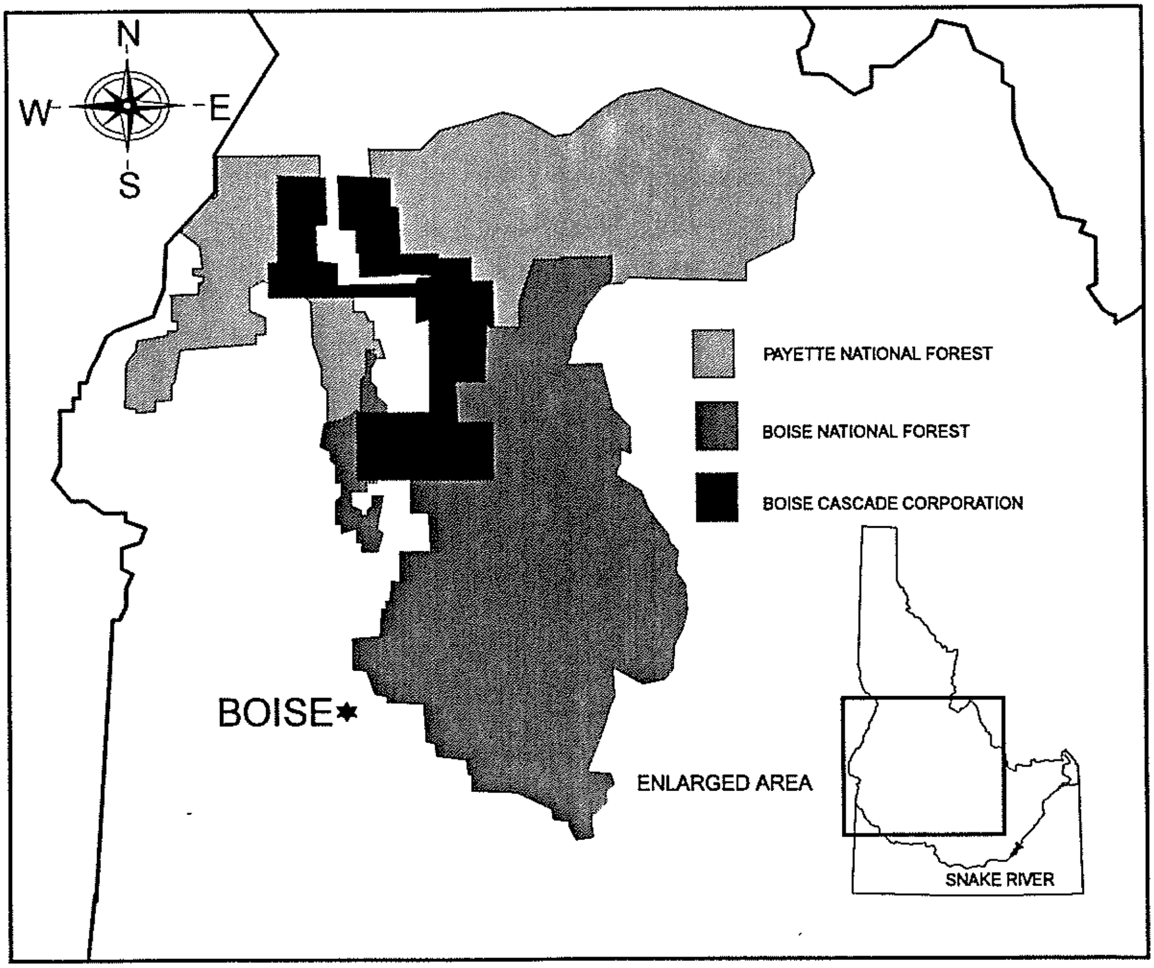


Figure 16-1. Location of lands in the case study.

Most of these insect species are normally present in the forests of southwestern Idaho, however, population levels remain at endemic levels until conditions are suitable for a major outbreak. Insect outbreaks on the two national forests in recent years have occurred primarily in concentrated locations corresponding to species mix, habitat type, and stand conditions.

Payette National Forest. The 1991 inventory of the Payette National Forest, confined to the 413,000 acres of suitable timberlands, showed mortality on the forest in the last five years was four times the mortality level in the late 1970s (Figure 14-5). The mortality from insect epidemics is expected to decline in the future, but the high mortality levels over the past five years have resulted in a loss in net growth, and a reduction in the volume of merchantable timber in the suitable timberland base. As might be expected from the analysis of growth and mortality rates on the Payette (Figure 14-5) a substantial proportion of the forest has mortality exceeding growth. In total, almost 46% of the suitable timberland on the Payette in 1991 was in this condition. Descriptions of the forest types where mortality exceeded growth are provided in Table 16-1.

With one exception—moderately stocked mixed conifer type on medium sites—all these forests had a stand density index exceeding

Table 16-1. Forest types with catastrophic mortality, Payette National Forest suitable timberlands, 1991.

Forest Type	General Stand Description	Average Age	% of Total Acreage*	Gross Annual Growth	Annual Mortality	Net Annual Growth	Mort./ Growing Stock	Mort./ Gross Growth	Basal Area	Stand Density Index
(Group-Site)	(Age: Stocking)	(years)	(%)	(cubic feet per acre)			(%)	(%)	(cf/ac)	(index)
Mixed Conifer-High	Mature/over-mature: Heavy	151	8.5%	60.5	97.1	-36.6	2.1%	160%	177	368
Mixed Conifer-Medium	Mature/over-mature: Heavy	157	8.2%	46.9	50.4	-3.5	1.2%	108%	158	302
Mixed Conifer-Medium	Mature/over- mature: Moderate	170	13.0%	32.6	40.4	-7.8	1.4%	124%	116	236
Engelmann Spruce	Mature/over- mature: Heavy/mod.	135	4.9%	41.3	397.8	-356.5	12.4%	963%	192	444
Engelmann Spruce	Immature/ mature: Heavy	88	0.8%	68.6	278.9	-210.3	6.3%	407%	240	575
Subalpine fir	Mature/over-mature: Heavy/mod.	128	4.2%	44.1	83.8	-39.7	2.5%	190%	165	440
Subalpine fir	Immature/ mature: Heavy/mod.	84	2.0%	41.9	69.5	-27.6	3.7%	166%	119	344
Lodgepole Pine	Mature/over-mature: Heavy/mod.	130	4.2%	35.7	40.7	-5.0	1.5%	114%	136	419

* Column sums to 45.8%

300. (See Daniel et al. (1979) for an explanation of how Reineke's (1933) stand density index is calculated and used.) However, it appears that stand density index is not a foolproof indicator of high mortality rates.

Table 16-2 presents data describing forest types comprising the remaining 38% of the Payette's stocked suitable timberlands that did not experience catastrophic mortality (16% of the suitable timberlands are burned areas, young growth stands, or unstocked clearcuts). Two forest types had a stand density index of more than 300. Heavily stocked immature to mature mixed conifer on high sites (stand density index = 365) had elevated mortality levels, with mortality taking 73% of the gross growth. From Figure 14-8, the expected regional range of variability is 15% to 35%. However, moderate to heavily stocked immature to mature lodgepole pine (stand density index = 415) had mortality taking only 13% of gross growth (Table 19-2).

Forest officials expect spruce beetles to kill almost all the commercial volume of Engelmann spruce. This is the predominant species on approximately 6% of the suitable timberlands. They expressed some concern for the health condition of the stands affected by high rates of mortality, but felt the mortality situation had peaked. They recognized the overstocked condition of stands had led to health problems, and suggested stand density index as an indicator of such potential situations.

Boise National Forest. Comparably detailed inventory data for the Boise National Forest are not available because of the differences in the timing of individual forest inventories. A new inventory of the Boise is not scheduled until 1995. But because of the current insect and wildfire situation, Boise National Forest staff members have estimated that the average annual mortality volume from 1988 to 1992 exceeded annual growth. More than 400,000 trees died from bark beetle attacks on the forest from 1988 to 1991. In addition, the Douglas-fir tussock moth defoliated more than 240,000 acres during 1990 and 1991 (Boise National Forest 1992e). The increase in Douglas-fir tussock moth attacks tend to weaken the tree and make them more susceptible to the Douglas-fir beetle. The predominance of older stands of Douglas-fir on the Boise continues to make Douglas-fir beetles a major concern. Wildfires have also killed substantial numbers of trees and timber volume during the 5-year period (Table 14-5).

Boise Cascade Corporation. The company estimated their mortality losses, from all causes, as ranging from 75,000 to 150,000 trees per year during the period 1987-1992, with salvage efforts recovering 8 to 10 million board feet, or roughly 45,000 to 56,000 dead and dying trees per year during the same period.

It is difficult to compare mortality losses across all three ownerships because of differences in the inventory systems used and the timing of measurements. Boise Cascade could estimate the mortality volume, but was unable to provide a breakdown of mortality from insect attack as opposed to other causes. Among those interviewed, it was generally agreed that Boise Cascade lands had experienced the lowest levels of mortality from insect attack. However, there are important differences among the three organizations. The national forests are managed for multiple uses, determined under a forest plan as required by the National Forest Management Act of 1976. Some of these lands are designated as suited for timber production, where timber can be the dominant use but all other uses and amenities are still important. Boise Cascade lands are managed primarily for timber production but other uses and amenities are important, including visual considerations, raptor sites, public use, and water quality.

Recent Insect Activity in Southwestern Idaho Forests

Sources for the following descriptions were personal interviews and the annual survey of insect activity conducted by the Idaho Department of Lands and USDA Forest Service (1991).

Table 16-2. Forest types without catastrophic mortality, Payette National Forest suitable timberlands, 1991.

Forest Type	General Stand Description	Average Age	% of Total Acreage[*]	Gross Annual Growth	Annual Mortality	Net Annual Growth	Mort./ Growing Stock	Mort./ Gross Growth	Basal Area	Stand Density
(Group-Site)	(Age: Stocking)	(years)	(%)	(cubic feet per acre)			(%)	(%)	(cf/ac)	(index)
Mixed Conifer-High	Immature/ mature: Heavy	90	3.5%	76.4	56.0	20.4	1.3%	73%	176	365
Mixed Conifer-High	Partial cut: Moderate	87	4.8%	54.0	19.6	34.4	1.0%	36%	90	199
Mixed Conifer-High	Partial cut: Light/mod.	100	1.39%	19.9	3.1	16.8	0.3%	16%	39	100
Mixed Conifer-Medium	Immature/ mature: Heavy	85	4.4%	73.9	5.9	68.0	0.2%	8%	142	286
Mixed Conifer-Medium	Partial cut: Moderate	89	10.9%	43.9	18.2	25.7	0.9%	42%	91	196
Mixed Conifer-Medium	Partial cut: Light/mod.	98	6.8%	18.8	3.5	15.3	0.5%	19%	36	95
Mixed Conifer-Low	Mature/over-mature: Low	169	4.8%	23.7	13.3	10.4	0.6%	56%	86	144
Lodgepole Pine	Immature/ mature: Heavy	88	2.0%	58.0	8.0	50.0	0.2%	13%	150	415

[*] Column sums to 38.5%

Mountain pine beetle (*Dendroctonus ponderosae*). Both the Boise and Payette National Forests experienced outbreaks from 1974-1984. On the Boise, the impact from this insect was primarily in lodgepole pine, and the current level of activity is low. On the Payette, the major outbreaks have been more recent with damage concentrated in white bark pine stands and small amounts of lodgepole pine. Large outbreaks in dense lodgepole pine stands are possible in the future on both forests.

Western pine beetle (*Dendroctonus brevicomis*). Infestations occurred from 1988-1990 primarily in dense stands of ponderosa pine on both national forests. About twice as many acres on the Boise as on the Payette were impacted by this insect.

Douglas-fir beetle (*Dendroctonus pseudotsugae*). Mortality from this beetle has been concentrated in large diameter-class stands of Douglas-fir on dry sites. This insect has been the largest cause of bark beetle mortality on the Boise in recent years. The increase in Douglas-fir tussock moth attacks beginning in 1990 tend to weaken the tree and make them more susceptible to the Douglas-fir beetle. The predominance of older stands of Douglas-fir on the Boise continue to make this insect a major concern. Douglas-fir beetle is less prevalent on the Payette, occurring mostly in inaccessible areas with potential increases in outbreaks because of the drought.

Douglas-fir tussock moth (*Origyia pseudopsugata*). The occurrence of Douglas-fir tussock moth increased dramatically on the Boise National Forest in recent years, from no detectable defoliation in 1989 to 36,800 acres in 1990 and 209,300 acres in 1991. Officials indicated that the population of Douglas-fir tussock moth collapsed in 1992 on the Boise. The Payette is currently experiencing defoliation from the tussock moth (11,000 acres in 1990 and 18,400 in 1991) for the first time in recent history. It is unclear as yet whether mortality resulting from Douglas-fir tussock moth will occur on the Payette.

Fir engraver beetle (*Scolytus ventralis*). When interviewed, national forest officials said recent drought conditions caused an increase in mortality from fir engraver beetles on both forests. Grand fir stands with an average diameter at breast height of 12 to 18 inches have been the hardest hit. Data on the impact of this insect is limited.

Spruce beetle (*Dendroctonus rufipennis*). Large scale mortality from the spruce beetle has occurred recently and is expected to continue on the Payette. Entomologists predict 85% to 90% of Engelmann spruce trees larger than 14 inches diameter at breast height will die over the next few years. The roadless timberlands on the forest have large acreages of dense older stands of Engelmann spruce that provide ideal habitat for the spruce beetle. This, according to forest officials, has been the major insect impacting the suitable timberlands on the Payette. Inventory data, however, show stands comprised predominantly of spruce represent only 6% of the suitable timberlands. No recent mortality was reported on the Boise from this insect.

Western spruce budworm. (*Choristoneura occidentalis*). Epidemic population levels of western spruce budworm occurred on the Boise from 1974-1987 and on the Payette from 1968-1985. The spruce budworm attacked, in descending order of severity, grand fir, Douglas-fir, and subalpine fir. A major recurrence is expected because of the large volumes of understory grand fir and Douglas-fir on parts of both forests. Activity now is mainly confined to the Weiser Ranger District of the Payette National Forest. The primary impact in the previous epidemic was growth reduction because of defoliation, dead tops, and loss of understory seedlings and saplings.

Response to Recent Insect Outbreaks

Individual national forests throughout the West have tended to develop their own responses to forest insect outbreaks, with direction from their forest plan, the regional office, and the Forest Pest Management section of State and

Private Forestry in the USDA Forest Service. This approach is consistent with the agency's decentralized planning process and allows each forest to respond to specific situations such as high levels of timber mortality. Many factors govern the response of a national forest to management issues, including access to the affected areas (that is, the extent of roading), the views of various interest and user groups, ecological factors, environmental laws (including the Endangered Species Act), professional judgment, and the forest plan. Boise Cascade's response to insect outbreaks has been to immediately salvage dead and dying trees to minimize losses in value resulting from degradation. Again, the difference in approaches reflects the management objectives of the organizations and the underlying laws governing the management of public and private forest lands.

Payette National Forest. Beginning in 1988, the Payette made a major shift in its harvest program to salvage accessible Engelmann spruce mortality on the suited timberland base and by the end of 1993 expected to have salvaged 200 million board feet. Salvage efforts on the Payette followed normal timber sale procedures, including the preparation of an environmental impact statement (EIS). The salvage program is now nearly complete in the roaded areas, but portions of the unroaded timber base have extremely heavy mortality and most of it will not be harvested.

The Payette placed a high priority on developing a comprehensive silvicultural and fuels treatment plan for the affected areas, and on the development of the forest's transportation system as part of their salvage program. This comprehensive prescription called for not only the salvage of dead and dying timber, but also the harvest of timber and other vegetative treatments under the selected regeneration system. Slash treatment and the construction of roads were also a part of the project. Given the magnitude and speed of the epidemic and the constraints faced in preparing timber sales, resource managers felt that only a small part of the infested acreage could be effectively treated. The Payette, therefore, concentrated their salvage program on their roaded timber base.

The rationale for this approach stemmed, in part, from the Payette National Forest Plan. Based on public input during the development of the forest plan, the forest chose to maximize back country recreation opportunities and concentrate timber production on the best sites. An analysis of yield tables indicated the forest could sustain historic harvest levels on about 431,100 acres, or about 18% of the entire forest. The plan was to take a tree farm approach, managing timber as the dominant use approach on those lands, with most of the rest of the forest to be managed primarily for nontimber product outputs (Payette National Forest 1986). However, many of the acres designated primarily for timber production were unroaded, with about 30% of the first decade's timber sale program planned to come from roadless areas. Hence, intensive timber management and access were considered crucially important to fulfill forest plan goals and objectives.

Planners believed the preparation of the EIS's needed for entry into the roadless areas identified as part of the timber base, and the likelihood of appeals or litigation, would have led to considerable delay between the time the sale was proposed and the time the timber could be harvested. The reduction of such probable delays was viewed as crucial for the economic feasibility of salvage sales, especially because of the rapid value loss associated with Engelmann spruce relative to other species in the region. The loss in value and increased cost of entering roadless areas would in all likelihood have resulted in these sales being substantially below cost, given stumpage prices during most of the salvage period.

In attempting to implement this approach to combat its mortality situation, the Payette encountered two complicating factors. First, critics have focused much of their attention on the tree farm approach for managing the forest's suitable lands, as outlined in the forest plan and approved in 1986. Virtually every timber sale is now appealed. Second, because a relatively large proportion of the 431,100 suitable acres are to be managed primarily for timber production, it is difficult to salvage sales or harvests of green timber at the levels projected in the forest plan, without violating the standards and guidelines set forth in the forest plan.

Boise National Forest. Given the large volume of dead and dying trees on the forest and the problems encountered by other national forests attempting to effectively address forest health problems, the Boise developed a forest health strategy in 1992 with three major elements (Boise National Forest 1992a):

> [1] ... a short-term measure to salvage dead and dying trees from lands suitable for commercial timber harvest to recover their economic value.
>
> [2] ... restore and improve forest health by reducing the number of trees competing for water. This longer-term measure will require thinning living trees over large acreages of commercial forest.
>
> [3] ... share information about forest health and methods to restore and improve the resilience of the forest ecosystems.

Salvage program.—While implementing the first part of their forest health strategy, the Boise elected to shift the 1992 sales program from the harvest of living trees to dead and dying trees, and salvage 67.5 million board feet of insect killed trees with an estimated value of $8.5 million. In 1992, 87 million board feet of salvage timber was sold. To speed up the salvage of dead and dying material the forest requested and received an exemption from appeals under 36 CFR 217.4 (a)(11). This regulation states:

> Decisions related to the rehabilitation of National Forest System lands and recovery of forest resources resulting from natural disasters or other natural phenomena, such as wildfires, severe wind, earthquakes and flooding when the regional forester or, in situations of national significance, the Chief of the Forest Service determines and gives notice in the federal record that good cause exists to exempt such decisions from review under this part.

Resource managers viewed this approach as crucial to avoid an estimated value loss of approximately 50% if the trees were left standing for one additional year on the site pending the preparation, review, and possible appeal of documents. The Boise National Forest (1992e) developed a position paper on the timber salvage and forest rehabilitation program, based in part on the support of federal legislation, specifically the Appropriations Act of 1992, which states:

> The managers urged the Forest Service to pursue a timber salvage program which will allow for the removal of maximum salvage volumes while protecting the full range of environmental values.

The Boise National Forest (1992e) concluded that the following policies and procedures reflecting Forest Plan intent were considered applicable when implementing the insect damage recovery and rehabilitation:

- The implementation of recovery and rehabilitation activities may only occur following site specific project analysis as stipulated by the National Environmental Protection Act.
- The implementation of recovery and rehabilitation activities may occur on both suited and unsuited lands on the BNF, in occurrence with standards and management area direction contained in the Forest Plan (BNF 1990, pages IV-57 and IV-61). The estimates are that more than 90% of the timber salvage and reforestation will occur on suited lands.
- The implementation of recovery and rehabilitation activities may occur within inventoried roadless areas, as well as roaded areas when current Forest Plan management activities provide for timber management activities.
- Salvage volume offered for sale under the Forest's policy to recover damaged timber resources will count toward the Forest's ASQ and will substitute for green volume harvested from suited lands. The Forest Plan ASQ (850 million board feet) will not be exceeded.

To gain public support for the salvage operation, the Boise National Forest made a substantial effort to involve the public in designing and reviewing the proposed action, including public meetings, letters to interested parties, and personal contacts. Although there was considerable support for salvaging the affected timber and rehabilitating the area, some interest groups and individuals expressed their preference for leaving most of the utilizable timber in the woods for long-term soil productivity and wildlife habitat purposes. Based on the scoping efforts undertaken, resource managers believed the salvage sales would be at risk of appeal, so the exemption procedure was used. The exemption process only eliminated the possibility of an appeal under the Forest Service appeals procedure; it did not eliminate the possibility of litigation based on the National Environmental Policy Act (NEPA) or other laws and regulations pertaining to the harvest of timber and its associated impacts.

Boise National Forest planners found it necessary to develop a streamlined approach for the preparation of NEPA documents and timber sale procedures if the salvage efforts were to be completed in a timely manner. Site-specific Environmental Assessments (EA's) were prepared for each of the affected areas, some of which spanned multiple drainages with scattered pockets of dead and dying timber.

The South Whitehawk Salvage Sale provides an example of how planners dealt with small pockets of dead timber across large areas. Approximately 5 million board feet of dead and dying trees on 1,100 acres was scattered throughout the 9,500 acre Whitehawk and No Man Creek drainages. Although two inventoried roadless areas contained 202 of the 1,100 acres, no new roads were needed because the entire sale was logged by helicopter. However, 12 landings (6 new and 6 reconstructed) were needed to support the yarding operations. These landings were located outside roadless areas in order to preserve roadless characteristics. In addition to the salvage harvest, 350 acres were designated for replanting. Insect baiting and trapping would be used in and around harvest areas to reduce insect populations. The number of snags were specified: for every 100 acres, 180 snags at least 12 inches in diameter at breast height (dbh) and 11 snags larger than 20 inches dbh were to be left after logging to meet wildlife requirements and to contribute to the structural diversity of the forested ecosystem. No trees or snags were harvested from old-growth stands delineated in the forest plan within the salvage area (Boise National Forest 1992c).

Dead and dying trees were not marked prior to the sale, in order to reduce the time required to prepare the salvage sales. Instead, sale contracts were designed to provide the needed information for designating trees to harvest within a specific sale area. For example, the Cayuse Point Salvage Sale included an estimated 5 million board feet of timber located on 4,300 acres. Bidders were provided with a map of the sale area and details of the sale specifications. For example:

- In logging the subdivisions numbered 1-3 on the Sale Area Map, all dead trees (slough bark and no foliage) meeting Utilization Standards, standing and down, are designated for cutting.
- During the period June 1 through December 31:

  [1] all trees retaining no green or red foliage are designed for cutting.

  [2] all trees with red foliage and which exhibit bark beetle infestation as indicated by boring dust from ground level to at least 6 feet high on the bole and/or brood galleries in the stump are designated for cutting.

  [3] all dead trees with sloughing bark and no foliage are designated for cutting, except for Douglas-fir and subalpine fir with red foliage and no evidence of bark beetle infestation.

Costs and time savings during the timber sale preparation phase were at least partly offset by increased sale administration costs and personnel needs during the actual salvage of the timber (Boise National Forest 1992d).

Thinning program.—The second part of the Boise National Forest strategy is to restore forest health by reducing the number of trees. This will be accomplished by thinning.

Will this program work? One benefit of a thinning program coupled with prescribed burning became evident after the Foothills Fire in August 1992. The lesson was described by USDA Forest Service fire scientist Bob Mutch (1993a) during an interview conducted by the Association of Forest Service Employees for Environmental Ethics:

> The Foothills Fire burned from late August into the middle of September. The fire wound up at something like 257,000 acres. It was a wildfire—started on BLM land—burned into the Boise National Forest. This fire, after it burned into Forest Service lands, burned primarily in the ponderosa pine type that also had this very significant encroachment of Douglas-fir over the past 50 to 60 years. The Foothills Fire burned at very high intensity and killed not only young-age stands, but killed old-age stands of ponderosa pine as well because it had that characteristic Douglas-fir ladder fuel present almost everywhere.
>
> But there was one very significant lesson that was learned on the Foothills Fire. There's a small 2,500-acre drainage in the Foothills Fire [called Tiger Creek] that had previously been thinned to improve the density of the stand to make it not quite so thick in young coniferous trees. And following the thinning operation, it had also been prescribed-burned. And so here was the opportunity to look at what thinning coupled with prescribed-burning did in terms of bringing the health of that stand through a very serious wildfire. That entire 2,500 acres came through the wildfire practically intact with very little mortality because the fuels had been removed through the thinning. Other fuels had subsequently been removed by prescribed-burning that left the stand in a very natural, more open condition that we would have expected to see there in pre-settlement times. That's the kind of lesson we would like to apply on a larger scale.

From a forest health standpoint, the lesson of Tiger Creek appears straightforward. Fewer widely-spaced trees receive more sun, water, and nutrients, and appear to survive wildfire better than their more crowded counterparts in fuel-heavy forests (McLean 1993). In addition to being thinned and burned with low-intensity prescribed fire, dead and dying timber in the managed forest in the Tiger Creek drainage had been salvaged (Idaho Forest Products Commission 1993).

Sharing information.—The third part of the Boise National Forest Strategy is public education and the sharing of information. Views of selected representatives of the environmental community were presented in Chapter 8 and indicate it may take more than education to convince some people that forest health presents problems needing solutions. As long as a forest health strategy is presented as a timber management strategy it is likely to encounter strong opposition from some quarters.

In November 1991, the Boise National Forest in conjunction with American Forests, a citizen conservation group based in Washington, D.C., brought together a large group of citizens, agencies, user groups, industry representatives, and others to discuss a strategy for dealing with the growing concerns about the health of the Boise. The result was the formation of a partnership by a letter of intent signed by a variety of partners to investigate the causes and to gather and share information.

While the partnership was taking shape, the Boise created a Forest Health Coordinator position to work with the partnership and to coordinate forest health management efforts. The first Forest Health Strategy brochure (Boise National Forest 1992a) was developed in May 1992 as a tool for informing the public about the Boise's strategy for confronting forest health issues. More than 30 presentations were made to local service organizations (such as Rotary and Optimist Clubs), congressional staff persons, state and local agencies, environmental groups, industry associations, and professional societies. Staff on the Boise actively worked to get the message out to local media with newspaper and magazine articles, television segments, and radio spots. Field tours were planned and more than a dozen were conducted for interested groups.

When the partnership was formed, American Forests put together an advisory group of local citizens, interest groups, state agencies, and other interested parties, including the University of Idaho, to help the partnership frame appropriate questions to guide the information gathering and sharing process. The partnership developed and sponsored a symposium in June 1992 (see, for example, Marshall 1993, O'Laughlin 1993) attracting more than 200 participants from federal and state agencies, interest groups, and citizens. The partnership also developed and sponsored a workshop in November 1993 titled: An Assessment of Forest Health in the Inland West. The proceedings will be published in the *Journal of Sustainable Forestry* (see, for example, Blatner et al. 1994, O'Laughlin et al. 1994) and in book form.

Other considerations.—In an effort to overcome the economic losses resulting from delaying salvage harvests Rep. Larry LaRocco (D-ID) has proposed forest health legislation in 1992 and again in 1993, that would give managers additional flexibility and resources to cope with these situations, but Congress has not yet enacted the bill into law.

In October 1993, a coalition of conservation groups filed suit to enjoin the Forest Service from exempting salvage sales from appeals (*Idaho Sporting Congress et al. v. USDA Forest Service* CIV 93-0390-S-EJL). Although the USDA Forest Service has been allowed to continue ongoing salvage sales for the present, the litigation has not been settled. However, it is now a moot point. The option of exempting salvage sales from appeal has been eliminated under the recently revised NFMA planning regulations.

Boise Cascade Corporation. Forest management on Boise Cascade lands is dramatically different than on Payette and Boise National Forest lands, for a number of reasons. First, unlike national forests, the company manages land with efficient timber production as the dominant use objective. Second, the company completed an extensive road network on their lands during the 1950s, thus allowing salvage logging of even relatively small volumes on a continuous basis. Third, the predominant harvesting system has been individual tree selection since the late 1940s (Boise Payette Lumber Co. 1947).

Harvest or leave tree selection criteria are adapted from Keen's (1936) classification system for ponderosa pine in the Black Hills region, which drew on the earlier work of Dunning (1928) in the Sierra Nevada. Keen specified four age groups and four vigor groups for a total of 16 classes, as follows:

> ... age group 1 = under 80 years; group 2 = 80 to 180 years; group 3 = 180 to 300 years and group 4 = over 300 years. Each age group is subdivided vigor groups based on crown into vigor, length and width, foliage density and condition and position groups A, B, C, D.

For example, Daniel et al. (1979) said, "tree class 4A would be a tree that was overmature, dominant, long and wide crowned and dense foliage with long needles."

Keen's classification system was designed to reduce insect losses, allowing the forester to move through the forest quickly, marking high risk trees for removal. The limitations of Keen's approach led Salman and Bongberg (1942) to adapt and refine the classification system. Boise Cascade adopted the use of Keen's system beginning in the 1960s and developed similar guidelines for Douglas-fir and grand fir. Boise Cascade has also developed individual tree selection rules to aid in achieving desired stand structures to be used in combination with Keen's classification

In the early 1970s the company developed stocking guidelines by habitat type to maximize growth and protect against bark beetle attack. These guidelines are achieved by selective harvesting, commercial thinning, and precommercial thinning. The company works to create a diversity of tree species wherever possible to reduce the risk of insect attack. Company forest managers believe this approach to tree selection and stocking control is a key factor in the relatively low levels of insect attack on their lands. The company's ability to rapidly respond to insect outbreaks over a well-developed road network is also an important factor to be considered in evaluating the relative effectiveness of this approach.

Viewpoints on Forest Health

Part of the problem with managing forests in the health context is disagreement between resource managers and some environmental groups regarding salvage logging. Resource managers view salvage logging as recovering economic value and hazard risk reduction. Some environmentalists, as detailed in Chapter 8, view salvage logging as a cure worse than the disease.

Forest resource managers. Discussion with forest managers indicated a definite perceived difference in management direction and levels of forest health problems. When interviewed by Garber (1992), Dave Van De Graaff, resource manager for Boise Cascade Corporation in southwest Idaho, expressed more concern about the future condition of the forest than acquiring a short-term glut of dead timber. He expressed pessimism about the future, because he doubts the USDA Forest Service will be able to protect enough of southwest Idaho's forest to produce timber on a sustained basis.

John Kwader, a unit forester with Boise Cascade, said he saw one crucial difference between what was done on company lands and national forests. The company trains its timber markers to select trees for harvesting, and sends them out with a paint gun only when they are experienced. It is the timber marker who will determine what the future forest will be like. The Forest Service, however, sends part-time seasonal employees out to mark its trees. The Forest Service manages the stands receiving treatment very intensively, but ignores silvicultural problems on high risk adjacent stands.

Herb Malany, chief region forester with Boise Cascade, said, "If you cut the old, weak, and wounded, you have a pretty good forest left." This philosophy, along with a greater emphasis on stand density management, describes the essence of the forest health management strategy for Boise Cascade. The company relies heavily on natural regeneration, and, as Malany said, "with the exception of a couple of habitat types, natural regeneration is successful."

According to Malany, thinned areas near Cascade, Idaho, were "graphically different" from unthinned areas where mountain pine beetles were a problem. Indeed, Boise Cascade has a photograph of a boundary between their land and an adjacent national forest tract. Trees on the national forest side of the line are red—obviously defoliated or dead; those on the company side are green. In the Idaho City area, unthinned stands of Douglas-fir suffered much more from Douglas-fir beetle. Malany said, "We see more problems on Forest Service land" in the Idaho City area—probably due to less thinning and logging in overstocked stands.

The company has experienced less mortality on its timberland from the fir engraver beetle in thinned areas. However, they have seen greater bark beetle mortality in stands that were opened up too fast; the grand firs were damaged by sun scald, then fir engraver beetle damage increased. Company policy is to not remove more than 40% of the basal area in the first entry. This is done to reduce sun scald, and also helps to reduce windthrow.

The impression from talking with Herb Malany, Steve Fletcher (Forest Health Coordinator, Wallowa-Whitman National Forest), and several foresters on the Boise National Forest is that the USDA Forest Service is constantly in a reactive mode, trying to deal with the aftermath of recent outbreak situations. Partially because of staffing problems, it takes all their time to prepare for actions in the problem areas, leaving no time to get ahead of the problems. The Forest Service also has much more mature and over-mature timber to deal with; Boise Cascade has cut more of their older age classes, and therefore has less material in susceptible conditions.

Discussions with John Olson, a forest scientist with Potlatch Corp., indicated generally the same impressions as with Boise Cascade regarding differences between national forest and company mortality situations in north Idaho. Because the company has less land in older age classes and practices density management, they see less mortality on their north Idaho land base than on adjacent national forest lands. Potlatch is currently seeing more western white pine mortality from blister rust than in recent years, but Olson was unsure how this compared with what might be happening on national forests. Potlatch does not have a monitoring system in place nor do they currently have specific guidelines for triggering action at given damage levels. The company is developing a system for monitoring forest conditions through aerial detection but this is not yet in place. They have selected an area intermingled with the Clearwater National Forest and will cooperate on developing a landscape management approach with their technical staff and geographic information system.

Selected views from environmental groups. Environmental groups have reduced the forest health management issue to salvage logging. Francis Hunt, lobbyist with the National Wildlife Federation, described forest health "as nothing more than a thinly veiled attempt by industry to increase the timber cut and weaken environmental laws" (Swisher 1992).

The benefits of salvage logging would seem to be a win-win situation from a forest health perspective. Quantities of flammable fuel are removed, reducing the potential of costly wildfires, and economic value is recovered. But not everyone agrees. Some environmental groups cite several objections to salvage logging. Some even say that salvage logging is just an excuse to help beleaguered national forest managers achieve their assigned allowable cuts (see Chapter 8).

Conclusions

It is difficult to evaluate the merits of the different approaches for addressing forest health conditions on the Boise and Payette National Forests and Boise Cascade Corporation timberlands in southwestern Idaho. These management responses involve specific situations encountered during different periods and in different places. Individual forest plans, national forest policy, and the management objectives of a private corporation prescribe three different sets of management guidelines. When comparing the approaches employed by the three organizations, it is important to remember that each ownership faced a unique set of issues. Because all three shared the same common goal of a healthy forest, something can be learned in each case.

The salvage program on the Payette National Forest preceded that on the Boise by five years, and with several key differences. The stumpage values for Engelmann spruce during much of the salvage period on the Payette were very low, generally under $50 per thousand board feet, compared to 1992 stumpage values at least 4 times as much. The low stumpage prices did not allow the use of helicopter logging for entry into roadless areas without building roads. The Payette, unlike the Boise, did not seek exemptions from appeals on their salvage program because the regional office did not support the use of exemptions until such time as the Payette was well along in their salvage program. The Payette did receive added funding from the salvage share fund to cover increased costs of the salvage program.

The major difference in management strategies is that the company practices stand density control on all its lands; the national forests have not historically placed the same emphasis on stocking control. All the resource managers interviewed expressed the need to get out ahead of the current tree mortality situation through an aggressive stand density management program. They felt current national forest stocking levels were too high given the drought conditions experienced over the past six years in southern Idaho and that density management was the key tool in controlling future insect epidemics, with or without drought conditions. All managers interviewed felt better stocking control could be accomplished through wider application of thinnings, prescribed burning, salvage logging, and other related cultural practices. Boise Cascade's use of a modified form of Keen's (1936) classification system to guide individual tree selection harvest combined with an extensive road network may have significantly reduced the incidence of insect activity on their lands. Conversely, stocking control will not solve all forest health problems on every site. Prescriptions must be site specific and consistent with existing or potential forest health problems.

Those interviewed said it was important to start building public support for management practices designed to promote the health and vigor of forests. At the present time, they said people do not get excited until the trees are red (indicating mortality).

Interestingly, resource managers and planners generally did not feel the recent insect outbreaks would substantially reduce near-term timber harvest levels below what would have occurred in the absence of these events. This is because the standing volume of timber and net growth rates are not the major limiting factors with respect to harvest levels on either the Payette or Boise National Forests. Recent developments related to a variety of other issues were felt to be far more limiting than the quantity of timber available for harvest. These include land and harvest component allocations made in the forest plan, threatened and endangered status of various salmon species that spawn in the Salmon River drainage, the unanticipated complexity of documentation related to compliance with the National Environmental Policy Act, and administrative regulations and changing public attitudes.

Forest managers in the region indicated three potential major economic losses or costs associated with the forest conditions in the area: increased costs of forest management activities, particularly in the form of significantly higher fire control costs; loss through decline in the value of various timber products resulting from the deterioration of wood quality in dead trees; and loss through reduced net growth and a reduction in the current inventory of merchantable timber.

It is clear that there has been a substantial loss of potentially merchantable timber and there is the potential for even greater mortality through future insect outbreaks and fire. It is unclear, given the constraints under which the national forests operate, if there has been any appreciable change in the volume of timber products actually available within southern Idaho because of the recent insect and fire situation. Salvage timber sales do not add to the amount of timber removed from the national forests when harvested from suited land where dead timber replaces green timber in the allowable sale quantity of the national forests. If salvage sales are to capture the economic value, they must be done expeditiously.

The Payette and Boise National Forests developed different strategies for approaching their tree mortality problems. The Payette placed a priority on developing a comprehensive treatment plan for the affected acres in the roaded portions of the suitable base. The Boise opted for a three phase approach, which stressed rapid salvage efforts, followed by cultural treatments designed to improve the vigor of remaining stands, and a comprehensive public education program. In each case the USDA Forest Service was confronted with appeals or litigation due to the public mistrust of such efforts.

Salvage sales will remain controversial with some resource managers, scientists, environmentalists, and members of the public at large. Regarding salvage sales and thinnings designed to improve forest health, the sharply different views held by resource managers and some members of the environmental community point to the need to develop a more participatory planning process. The proposed planning process should recognize the need for and value of collaborative efforts designed to increase the general public's understanding of and involvement in resource management decisions. Simultaneously, resource managers should be willing to learn from the public as well. After all, everyone shares a common goal—a healthy forest.

Chapter 17. Future Directions

Forests will continue to be important to humans, for many reasons. Nemetz (1992) expressed these reasons succinctly:

> Throughout history, forests have played a central role in the development and, indeed, survival of humankind. Despite the profound differences between the world of the twentieth century and early history, forests continue to nurture human beings—with fuels that heat our homes and fire our industry, with structural materials that transport and shelter us, and with paper that lends permanence to our transitory thoughts and endeavors. While it is difficult, if not impossible, to imagine the evolution of our modern world without the tree and its prodigious harvest, it has become increasingly apparent in the last few decades that forests serve an indispensable function in a complex ecological system which sustains not only the human species but all life on our fragile planet.

Given that forests provide for many human needs and will continue to do so, how do we sustain forest ecosystems while meeting human needs? Replies to this perplexing question show the need to take a broader perspective on resource management concerns. That is what forest scientists and resource managers are doing as they formulate research questions in the context of forest health. That is also what scientists and managers are doing as they develop principles for ecosystem management. Forest health and ecosystem management are about sustaining forest ecosystems while providing for human needs. Where we go from here will be determined by social and economic as well as ecological needs. Scientists and managers are beginning to form partnerships to move off in the directions needed to sustain forest ecosystems. Those partnerships must include the public. If they do not, they will fail on the issue of public trust.

Brooks and Grant (1992) commented about the widespread recognition that human population growth, coupled with increased resource use, is reaching a level that cannot be maintained without damaging natural systems. In some cases sustainable rates may have been exceeded. Few people deny that resource limits exist, but there is no consensus on where those limits are. Even as resource limits are approached, the list of commodities and services people want from forests gets longer. Forest managers are frustrated by the challenges of satisfying these diverse and often conflicting expectations (Brooks and Grant 1992).

Alternative directions are straightforward, but there is a fork in the road. Some people trust scientists and managers to work out the solutions to sustaining forest ecosystems. Others say it is the scientists and managers who created the problems, and they should not be trusted with solutions to today's resource management problems. Some people say nature, not science, has the solution to today's problems—leave the resources alone. Others don't even recognize that problems exist. Being scientists, we take the position that science can help provide replies to sustainability questions. Yet we recognize that not everyone will accept this position. Only open and collaborative dialogue between interested parties can restore the missing element of trust.

Forest protection was one of the first concerns of forest managers in North America. Their task was to manage forests conservatively so these systems could provide present and future generations with many benefits. The role of forest managers has not changed, but our level of knowledge has. Today some people think the best way to protect forests is to leave them alone. Many forest scientists and resource managers have difficulty comprehending this view of the world.

The responsibility for current resource conditions and problems is shared by land managers of yesterday and today. Until recently, scientists have been slow to grasp the comprehensive ecosystem view of natural resources (R. Everett, review comments). Scientists and land managers are developing techniques to improve current conditions based on proven techniques and developing knowledge of how land management affects a wide array of resources. The questions concerning what to do next do not have answers as simple as leaving the forests alone.

Actions Regarding Idaho's Forest Health Condition

The older concept of pest damage prevention can be expressed in the new terminology of forest health (Byler and Zimmer-Grove 1991). Each insect pest and each tree disease has unique characteristics and requirements for survival and growth. Protection from catastrophic wildfire is also an important aspect of forest health. Review of the important forest insect and disease outbreaks in the state and region reveals common conditions that lead to major outbreaks.

Because of the lack of a widely accepted definition and understanding of forest health, and the infancy of forest health monitoring, only some inferences can be made at this point regarding operational strategies for managing forests as healthy ecosystems to sustain the many values people desire.

Past management practices and policies coupled with unfavorable weather patterns have helped create conditions leading to elevated levels of insect and disease activity in Idaho's forests.

Forest health condition does not define how a forest should be managed. People need to determine forest management objectives, and then the condition of the forest can be appraised in terms of the objective—can forest conditions support the desired purpose? The forest may need to be altered by management activities so that it can be put in the appropriate condition to achieve the desired objectives. One should therefore expect different desired forest conditions now and in the future for forests used predominantly for timber production, or watershed protection, or wildlife habitat, or scenery, or recreation, or wilderness. It is possible to provide some of these values in one forest stand, but not all of them. Only when forests are viewed from the larger landscape perspective can multiple use be considered a feasible strategy.

Forestry appears to be in the midst of a revolution, driven by public perceptions, public debate, and public policy (Brooks and Grant 1992). People need to be involved in decisions about managing natural resources on public lands. Environmental groups are not opposed to the idea of maintaining the health of ecosystems, nor are forest industry groups, or professional resource managers. These groups, however, may prefer different means to achieving the same goal. Cubbage et al. (1993) addressed this point in a chapter on "Environmentalism, Conservation, Ethics, and Professionalism":

> Beauty, health, and permanence—the ideology of environmentalism is captured in these three words that are the title of Hays' (1987) historical treatise on the politics of the modern environmental movement.... Sometimes modern-day environmentalists favor managed forests; more often, they do not.

The above statement implies that health maintenance should not detract from beauty, and must contribute to permanence. Ecosystems are dynamic, moving through various stages of development in concert with environmental conditions and biological interactions. The system doesn't come and go, but it may be expected to change its state. What management strategy is best for the forest? Some say leave it alone, others say apply research-based knowledge to help provide what society desires from its forests.

Brooks and Grant (1992) rejected the notion that troubles faced by forest managers are the product of an unappreciative public stimulated by "radical environmentalists." The findings of forest science, they said, are what should force the forestry profession to rethink its approaches to management. We agree, and identify in the following sub-sections the actions necessary to improve forest health conditions in Idaho. These include the development of partnerships between scientists, managers, and the public along with an adaptive approach to management. Also maintenance of stand conditions that promote health by having appropriate species composition, tree numbers best suited to site conditions, and reducing risk by removing hazardous levels of dead and dying trees.

Some ideas for filling in some our knowledge gaps are detailed in the **Research Agenda** section.

Management strategies. A variety of management strategies have been suggested for dealing with insect, disease, and wildfire outbreaks. An alternative favored by some people is to take no action and let natural events prevail. Others, such as Sampson (1992b) believe aggressive action is warranted. He asked, on behalf of his group American Forests:

> So is it "crying wolf" to suggest that the situation in today's forests constitutes an emergency that warrants aggressive, pre-emptive action to prevent disaster? We don't think so. People buy life insurance, not because they're likely to die within the next year but because they want to protect loved ones from the terrible impact should that unlikely event occur. Forest investments should be viewed in the same way. That logic would allow us to invest in prudent efforts to improve forests, reduce the risks involved, and give the forests a better chance to continue to provide the benefits of a healthy ecosystem.

According to the National Forest Products Association (1992), the federal land management agencies seem to be locked into a strategy of identifying a forest health problem, waiting for nature to take its course by killing the trees, then struggling through a cumbersome timber salvage sale process in hopes of recovering a small amount of infested trees before they infect other trees, or fuel fires on adjacent stands. The association, which was renamed the American Forest and Paper Association in 1993, stated that this strategy is inefficient, costly, and does little to improve forest health. The association said the Forest Service needs to correct two failed strategies to insure future forest health. First, the effort to completely suppress fire in our forests has stalled natural cycles and wrought disease and insect pests in many national forests. Second, species composition and stand density must be managed to reduce the impact of drought on the forests. Stand density is particularly important in time of drought when water is limited. Species composition ensures drought-resistant species will be retained for future forests (National Forest Products Association 1992).

Byler and Zimmer-Grove (1991) of the USDA Forest Service came to the following conclusion:

> A forest health strategy needs to be based on an understanding of forest ecology and insect and pathogen ecology. The practice of achieving and maintaining healthy natural forests is accomplished through silvicultural practice that is based on this understanding.
>
> But major challenges remain and new ones face us. The progress we have made is with stands managed primarily for timber. Insect and disease activities continue in unmanaged stands and stands managed for other values. Some of the changes they cause, such as an increase in the risk of wildfire, affect non-timber values of those lands. Methods for managing such stands using prescribed fire and perhaps other means are needed. Non-management can lead to undesirable insect- and disease-caused changes. The exclusion of fire, sometimes needed for human safety and other reasons has increased insect disease outbreaks in Douglas-fir forests. To ignore the responses of insect and diseases to major shifts in stand composition, stocking and structure, can intensify already serious problems. The lessons of the past are that insects and pathogens respond to ecosystem changes, that not all of these responses can be foreseen, and that the effects of these experiments may not be apparent for several decades.

The Associate Chief of the Forest Service (Leonard 1992) summarized the need for specific management actions in testimony before the U.S. Congress:

[a] Reducing stand susceptibility to insects and disease through silviculture treatments.

[b] Shifting harvest from lower-risk stands to high-risk stands.

[c] Evaluating and treating fuel accumulation to reduce the threat of wildfire in the urban interfaces.

[d] Reviewing and modifying forest plans as needed to better address forest health concerns.

[e] Intensifying monitoring for Gypsy Moth and eradicating it when detected.

[f] Initiating, in 1993, an Idaho Forest Health Monitoring Program based on the annual insect and disease surveys.
[Note: this has not been done.]

[g] Comprehensively assessing forest health as part of the Intermountain Region's implementation of ecosystem management.

[h] Conducting research on root disease, bark beetle prevention and management techniques, and the use of prescribed fire to maintain ecosystem health.

Sampson summarized several key points from a forest health symposium co-sponsored by American Forests, which focused on the Inland West (Clark 1993c):

> Forest managers need to use the best available science and listen to citizens; focus on outcomes and save the "pieces" of ecosystems in the process; and strengthen partnerships with outside organizations, heightening citizen involvement and education.

Involving citizens in the partnerships Sampson referred to above will be the key to achieving the healthy forests that everyone desires. Without public support, forest management cannot succeed for long.

Forest managers will need to adapt to changing situations. Adaptive management as applied to forestry means forest management capable of adapting to social changes and demands on the forest; of adapting to characteristics of the ecosystems and sites where it is applied; of adapting new scientific knowledge and techniques; and of adapting to new conditions yet to be experienced, such as global climate change, drought, fire, and insect and disease epidemics. By maintaining diverse and fully functional ecosystems, both managers and forests can adapt and respond (Adams 1992).

Stand Management

A review of forest ecology and management case studies indicates that stand management will be an important strategy in restoring and maintaining healthy forests. The two most important considerations in Idaho are species composition and density control.

Species composition. Past management practices have changed the composition of Idaho forests from pine to fir. Timber harvesting and fire suppression are largely responsible for the changes. Pines are well-suited to Idaho sites and environmental conditions; firs less so. Forest health can be promoted by favoring species that are best able to withstand changing environmental conditions and natural disturbances.

Density control. Overstocking is a forest condition leading to weakened trees, making them susceptible to pest damage (Stewart et al. 1984). Most of the forest health problems associated with insects and disease in the West, according to McDonald (1993), are occurring in forest types normally characterized by 10 to 30 year fire frequency intervals, and in which fires have been excluded by decades of suppression efforts. The common thread in these situations are trees growing at their maximum drought tolerance in stands that by historical standards are overstocked (McDonald 1993).

The case study in Chapter 16 identified stand density control as the most important component of a forest health management strategy in southwestern Idaho, where moisture is the limiting factor. Thinning is the appropriate action in many cases.

Wildfire hazard reduction. In the prolonged absence of fire, hazardous fuel situations often develop. The combination of dense understories, accumulated deadfall, dying shrubs, and other accumulated litter and debris can produce fires severe enough to scorch the crowns and kill the cambium of overstory trees, and intense enough to reduce soil organic reserves and have the potential to leave deficient nutrients for the next successional cycle.

How much fuel is too much? Harvey et al. (1981) suggested amounts of organic matter in excess of 11 to 17 tons per acre can be considered undesirable, especially on dry sites. What can be done about it? Guidelines provided by Brown et al. (1985) can be used to write fire prescriptions for safely reducing the hazard of fuel buildup. Prescribed fire can also be used to reduce the hazard associated with logging slash resulting from clearcuts and partial cuts. Most fire prescriptions can be written so as to accomplish silvicultural, range, and wildlife objectives as well as wildfire hazard reduction (Fischer and Bradley 1987).

From a fire management perspective, a successful prescribed fire is one that is executed safely, burns under control, accomplishes the prescribed treatment, and attains the land and resource management objectives for the area involved (Fischer and Bradley 1987). Such planning should be based on the following factors (Fischer 1978):

[1] Physical and biological characteristics of the site to be treated.

[2] Land and resource management objectives for the site to be treated.

[3] Known relationships between preburn environmental factors, expected fire behavior, and probably fire effects.

[4] The existing art and science of applying fire to a site.

[5] Previous experience from similar treatments on similar sites.

When properly applied, Holdorf (1982) said prescribed fire has a low risk of causing long-term adverse affects on soil fertility. However, the intense heat and ashes from burning dozer-piled logging slash can affect regeneration success on the area occupied by the piles. Therefore, size of piles should be kept small, and burning should be deferred to periods of relatively high fuel and soil moisture (Holdorf 1982).

Mutch et al. (1993) laid out the future directions when they said the use of prescribed fire will need to increase about ten times from current levels to restore and maintain healthy seral pine and larch forests. This will require new approaches to planning, financing, and conducting prescribed fires. The cost of such a burning program will likely be larger than one budget line item can support. Benefits accrue to more than one resource, suggesting that prescribed fires be funded through multiple budget line items, including wildfire hazard reduction (Mutch et al. 1993).

If such a program is implemented, education efforts will be needed. People will need to consider whether the certainty of smoke from periodic hazard reduction fires that produce additional wildlife benefits is preferred to the risk of intense wildfires that set the ecological clock back to zero.

Timber salvage guidelines. The economic and ecological benefits of salvaging timber argue strongly in favor of that alternative, as long as enough woody material is left behind on the site. How much is enough?

It is important to retain a certain amount of woody material for wildlife habitat and the maintenance of forest site quality. Harvey et al. (1981) found ectomycorrhizal development in western Montana was stimulated by the presence of decayed wood in the soil. Decayed wood also has a moisture and nutrient regime often favorable to continued seedling growth. These potential benefits are especially important on moderately dry sites. Scattered large logs left on a site also retard soil movement and provide shade for young seedlings. Harvey et al. (1981) suggested that about 11 to 17 tons per acre of fresh residues larger than 6 inches in diameter should be left on the site following logging and burning. Another important reason for leaving moderate amounts of large diameter woody debris scattered on the site following logging and burning is to supply food and cover for wildlife (Fischer and Bradley 1987). Prescriptions need to be developed to integrate snag retention, snag replacement, and downed woody materials guidelines based on the life expectancies of these forest components in relation to future timber harvests.

The need to retain moderate amounts of scattered large-diameter woody debris should not preclude slash disposal or the removal of dead and down woody debris. Slash and debris represent a significant fire hazard on most sites that will exist for at least 3 to 5 years, even with a maximum compaction effect from winter snows (Fischer and Bradley 1987). Some slash and debris disposal will be necessary for fire protection, reforestation, and movement of wildlife. Additional research is needed to determine how much and what size and type of slash should be retained (Adams 1992). Some slash and debris disposal is also necessary for recreation enhancement, because scenic beauty is reduced by debris or slash, as is traversibility by hikers (Brunson and Shelby 1992).

Research Agenda

Scientists do not know everything there is to be known about managing forest ecosystems, and never will. Some avenues of research will enhance our knowledge of managing forest ecosystem health more than others. Those include the sub-sections herein: silviculture, hazard rating and risk analysis, integrated inventories, and ecosystem modeling.

Clarkson and Schmandt (1992) said scientists now generally agree there is no single casual factor responsible for forest decline. Instead, there are a variety of human activities interacting with natural events and processes. Together, they induce stresses in forests that culminate in the decline of individual trees, populations, and whole ecosystems. The multitude of long-term changes in affected areas results in a formidable web of interactions, all of which makes the research task very complex and time consuming (Clarkson and Schmandt 1992).

Gray and Clark (1992) recognized that scientists have only begun to study forest health from an ecosystem perspective—one encompassing all the basic elements such as plants, animals, and soils, plus processes affecting forest health at various geographic scales. Therefore, we do not yet have as solid a scientific basis for management actions as some people would like, and ecosystem complexity insures we never will. But that doesn't mean we should do nothing. Forest systems are at high risk, as are many human values in and around them. There is insufficient time to generate and test hypotheses in order to find proven practices for preventing unhealthy conditions or restoring health to affected forest ecosystems. Instead, scientific research, new management approaches, and policymaking efforts must proceed simultaneously, with specific provisions for future adjustments as new information becomes available. This approach creates a synergy of its own. Scientists become more active players in the policymaking process, resource managers work more closely with scientists to begin implementing new practices, and policymakers become better versed in rapidly evolving scientific and management debates (Gray and Clark 1992). This fast-track approach will require an implementation of the principles and guidelines of adaptive resource management (see Holling 1978, Walters 1986).

Brooks and Grant (1992) observed that the role of forest scientists is changing. Once scientists offered managers tools they thought could control natural systems based on thorough, controlled experiments. This strategy did not prevent insect and disease epidemics. Now scientists must identify uncertainties and point out the complexities of systems, within limited time frames and in the presence of contentious debate over values. Advocates of intensive forestry are now asked to prove that these practices are benign, whereas in the past, critics were forced to prove them harmful, for example, to wildlife (Brooks and Grant 1992).

According to the National Council of the Paper Industry on Air and Stream Improvement (NCASI 1993b), the forest products industry has taken a pragmatic approach to forest health research. The industry conducts technical studies on forest health that [a] independently address the scientific rigor and interpretation of existing research, and [b] identify and address gaps in knowledge that are of special concern to the industry. Cooperative studies on forest health are currently underway in the areas of air quality, global change, and forest management. The industry's Forest Management/Forest Health Program, begun in

April 1993, is addressing technical concerns about ecosystem management and sustainable development. The strategy is to develop information and models needed to compare overall costs and benefits of alternative forest management systems and policies (NCASI 1993b).

According to Smith (1990), greater emphasis is needed on education, research, and monitoring of forest health. In addition, forest health practitioners need multidisciplinary competence. Atmospheric science, soil science, fire science, biochemistry, meteorology, climatology, physiology, ecology, entomology, and pathology can all contribute to our knowledge of forest health. Research information needs to be synthesized and integrated (Smith 1990).

Quigley (1992a) added the social science dimension to forest health concerns, and much more work needs to be done here. For example, a simple solution seems to be to return fire to Inland Northwest forest ecosystems, using fire science. However, the social problems associated with smoke likely will preclude widespread use of prescribed fire to achieve desired forest conditions. Shelby and Speaker (1990) pointed out that people place a high value on air quality, and may oppose prescribed burning for several reasons, including public health and aesthetics.

Wickman (1992) offered several recommendations for research and development approaches for dealing with forest health problems in the Blue Mountains from a pest management perspective:

[1] Develop silvicultural and nutrient management techniques, pheromones, and environmentally safe pesticides to reduce impacts on resources in high-value stands.

[2] Conserve remaining old-growth ponderosa pine, especially to preserve the gene pool representing inherent vigor and survival traits.

[3] Undertake experimental stand conversion and maintenance techniques on a landscape level.

[4] Study interrelationships of plants and animals to minimize loss of biodiversity and productivity.

[5] Initiate long-term studies of nutrient cycling.

[6] Improve techniques for monitoring pest population and stand health.

[7] Develop and improve models used in the national forest planning process.

Silviculture. Outbreaks of pests in the Inland West, said Byler and Zimmer-Grove (1991) are symptomatic of ecological disturbances in forest ecosystems. Human activities in the past century have altered the character of forests. In most cases, these forest conditions are reversible through silvicultural techniques. The management of silvicultural systems must consider the role of pest agents and how they respond to management practices (Byler and Zimmer-Grove 1991).

Filip and Schmitt (1990) reviewed silvicultural options for managing diseased fir stands in Oregon and Washington. Firs are a valuable and expanding resource, but are highly susceptible to a myriad of forest pests, so they need to be managed—if indeed they are to be managed—with consideration for these pests. Much of that knowledge is applicable to Idaho. These two forest pathologists specifically addressed root diseases, stem decays, and dwarf mistletoes which, in addition to insects, affect productivity. Three characteristics of forest stands—composition, structure, and age—can be manipulated with silvicultural treatments to minimize pest damage. [1] Stand composition (species and density) is probably the most important and most controllable of the three. [2] Stand structure can be varied to minimize pest impacts, with mixed-species stands being safer than single species stands. Care must be taken, though, because pathogen activity resulting in mortality can actually be prompted by all-age management through single-tree selection and salvage cutting. [3] Stand age affects disease impact, particularly from stem decay, which generally increases in incidence and severity with tree or stand age (Filip and Schmitt 1990).

Silviculturists have several options for minimizing timber losses from pests in true fir stands. There are six of them, reviewed by Filip and Schmitt (1990) as follows: [1] type of regeneration—planting, natural regeneration, and advance regeneration; [2] precommercial thinning, which offers several advantages that recommend more widespread use of this option; [3] commercial thinning, which has many of the advantages of precommercial thinning, but some additional disadvantages that need to be addressed with modified logging techniques; [4] prescribed burning, which can effectively help with fir regeneration, but because fire can help eradicate fir from a site it is therefore not recommended as a thinning tool when fir is to be maintained as a crop; [5] fertilizing, which research has shown there are several good reasons for doing to reduce future losses in fir stands; and [6] final harvest, which is the best time for controlling root disease and some other pests as well because many of the affected or susceptible trees can be removed or destroyed. Although clearcutting has some disadvantages, it usually presents fewer pest management problems in true fir stands because there are no residual trees to be windthrown, to infect regeneration, or damage regeneration upon subsequent removal, which is a problem with seed-tree or shelterwood harvesting (Filip and Schmitt 1990).

Can silviculture replace the role of wildfire? Graham (1993) answered the question affirmatively. Silviculture is the art and science of managing forests to meet management objectives. Wildfire, in contrast to silviculture, does not alter forest structure and composition according to management objectives. Wildfire is opportunistic and unpredictable. Silviculture and prescribed fire can produce similar effects on forests. The practice of silviculture has the knowledge and tools to complement if not replace many of the processes associated with fire in many forest ecosystems. The practice of silviculture is just as capable of developing prescriptions to sustain a wide variety of forests and forest amenities as it is in producing forest crops. Some of the impacts fire has on vegetation can be achieved with silvicultural practices, but beneficial changes to the soil resource may be harder, if not impossible, to achieve. Instead of attempting to replace wildfire with other silvicultural tools, it would be prudent to fully integrate prescribed fire into silvicultural prescriptions for sustaining healthy forest ecosystems. If society desires forests to be managed for sustainability and function, silvicultural prescriptions can be developed to do so, and many of the tools that can produce timber crops can be applied (Graham 1993).

The use of tried and proven silvicultural tools is an important future direction for improving forest health.

Hazard rating and risk analysis. Diverse forests are better able to adapt to change and withstand disturbances. Diverse forests are more easily sustained, and more socially acceptable. This is not a new concept. For example, bark beetle hazard rating schemes include species composition as one of the most important variables. Insect epidemics are more likely to occur in pure stands than in those with mixed conifer species (Adams 1992). Different tree species also react differently to limited moisture and nutrients. Dense stands are at more risk during drought because more trees have to share limited moisture, thus stressing the stand and putting it at risk.

Beuter (1991) said there is a need for better understanding of risks associated with alternative courses of action, potential opportunities for compromises in land use allocation and land use practices, and for developing a shared vision of what is meant by multiple use and the sustainability and availability of forest resources now and in the future. Risk analysis is expensive and trust in the ability of resource managers and woods workers to do the right thing has to exist before risk analysis can be justified. Otherwise, the analysis will not be persuasive to those who don't believe that management activities can achieve desired results (Beuter 1991). Risk analysis, however, can help gain the trust of the public by demonstrating how different management approaches change risk situations (M. Brunson, L. Norris, review comments).

The task of forest scientists is made difficult because people have different opinions on the type and distribution of risks that are acceptable (Brooks and Grant 1992). Nash (1991) observed that scientists themselves are often of differing opinions with regard to risk. Ecologists are inclined to look askance at economists who insist on assigning monetary values to everything, including intrinsic values of ecosystems. A closer interdisciplinary dialogue here would be useful (Nash 1991).

Integrated inventory. The Chief of the Forest Service asked each of the nine Forest Service regions for strategies to implement ecosystem management. One of the common themes that emerged was the need to develop an integrated resource inventory uniting information on ecological relationships with earlier resource databases (Clark 1993a). An improved inventory is a key need in Idaho. The forest products industry recognizes this need and has made several suggestions for improving inventory methods (American Forest and Paper Association 1993).

Modeling. Some scientists studying ecosystem health feel modeling will provide answers to management questions (Costanza 1992). The experiment in building an elaborate and expensive model during the 1980s for the National Acid Precipitation Assessment Program is somewhat instructive, regarding appropriate modeling scale. Over the course of a decade, 2,000 scientists worked to provide new information as part of the Clean Air Act Amendment of 1990. A congressional aide said all that work was "totally irrelevant." Others say it helped frame the debate (Roberts 1991). The point is that a model won't answer difficult questions, no matter how elaborate it is. A conceptual model of forest ecosystem health would help determine which components should be assessed, and would help to frame the debate on sustainable ecosystem management.

Reduced growth rates are a significant contributing factor to tree mortality (USDA Forest Service 1982). Tying together growth reductions with surveys of insect and disease damage is one example of modeling at an appropriate scale. Existing data and models could be used to predict the role of pests in reducing growth rates. This could be done using forest growth projection models —one example is Prognosis (Stage 1973, Wykoff et al. 1982, Stage et al. 1990)—to "grow" stands of various kinds under scenarios with and without effects of pests. We have demonstrated some preliminary findings from work of this nature by Hagle and Byler (1993) in Figure 15-2. Simulated growth reductions could be applied to acres of infestations determined during annual assessments of foliar damage.

Ecosystem Monitoring Indicators

Integrated inventories and ecosystem modeling are closely related to the indicators of ecosystem condition selected as appropriate focal points. These should be chosen to enhance monitoring efficiency while representing important ecosystem characteristics. In forests, it goes without saying that vegetation and watershed indicators are important, and we are close to implementing effective monitoring of these elements (see Chapter 13). Wildlife are a key ecosystem component. More research on their value as indicators is required, and an agenda is suggested in this section.

Smith (1990) said we must expand our long-term monitoring of forest lands. Monitoring is crucial to maintain forest health effectively and intelligently, and to point out areas where additional knowledge is needed. Miller-Weeks (1992) asked, as researchers set out to monitor forest health, are they looking at the right things? Are they sampling correctly? The Forest Service's Eastside Ecosystem Health Assessment (Everett et al. 1993) recommended a three-part monitoring strategy, including [1] landscape structure and composition, [2] sensitive species and unique habitats, and [3] disturbance regimes, effects, and hazards.

They said benefits in monitoring efficiency are derived when common attributes measure two or more things simultaneously. This proposed system complements but does not duplicate monitoring programs described for terrestrial and aquatic ecosystems in the U.S. EPAs Environmental Monitoring and

Assessment Program (EMAP). To avoid a monitoring quagmire, further efficiencies should be explored, and scientific and public consensus achieved on appropriate strategies. A "short list" of important monitoring variables should be identified to accomplish representative and cost-effective monitoring (Everett et al. 1993).

Based on the evidence available for Idaho forests, existing data collected by the USDA Forest Service to analyze insect and disease levels is a starting point. Data collection procedures could be refined to collect more reliable information. Data from forest resource inventories is also useful. Marsden et al. (1991) described how to use forest inventory data for sampling pest occurrence in interior Douglas-fir forests. One weakness is that effects of disease may be understated in inventory data (J. Byler, pers. comm.; Partridge and Bertagnolli 1993).

Relative abundance of wildlife. Birds and small mammals have been identified as priority research topics for monitoring forest ecosystems as part of EMAP (Hunsaker et al. 1990). Other groups of animals that have less priority include salamanders, lizards, ground-dwelling beetles, ants, snails and slugs. EMAP is a national program and has a broad focus. Due to financial and logistical problems, EMAP may not evaluate many monitoring options potentially available to forest managers in Idaho. However, there are many conclusions and research questions or agendas identified by EMAP that apply at any scale. These include: [1] the rationale for focusing on birds and small mammals, [2] research supporting the selection of species to monitor, [3] the evaluation of monitoring protocols, including methods and sampling design, [4] estimating the sensitivity of the animal indicators to environmental stress, [5] evaluation of the concept of monitoring keystone species, [6] development of nondestructive, cost-efficient techniques for monitoring and bioassays, [7] development of an index to terrestrial animal integrity, and [8] the potential to monitor guilds, or sets of similar species, rather than single species (Hunsaker et al. 1990). Implicit in much of this agenda is the need to take an experimental approach to answer these questions quickly and rigorously.

Numerous species of birds and small mammals inhabit the forests of Idaho, making the determination of the appropriate species or guilds to monitor a difficult task. The indicator species listed in each national forest plan may provide a starting point. Reviewing pertinent information on all candidate species and making the most appropriate choices would be another approach. However, due to the lack of information on many species, the chance exists that the most representative species may not be assessed. An alternative method is to begin studies of a variety of birds and small mammals and determine those that serve as effective indicators of habitat conditions. Primary considerations involving these determinations are the complexity and accuracy of the monitoring techniques and the potential to obtain estimates of variance. To meet these considerations new techniques and sampling protocols may have to be developed. In addition, some species are more amenable to simple and accurate monitoring by field personnel than others.

Some species are considered habitat generalists (e.g., dark-eyed juncos and deer mice), inhabiting a variety of habitat types and successional stages, while others are habitat specialists (e.g., pileated woodpeckers and red-backed voles), found only in a limited number of types or successional stages. Fluctuations in populations of generalists may indicate a large-scale phenomenon affecting forests, such as global warming. Habitat specialists may provide information on the state of forests at finer scales, such as landscapes, habitat types, and stands.

Monitoring the large number of different species of birds and small mammals using forests can get complicated and necessitates choosing a smaller subset of species. This embodies the indicator species approach and its inherent problems (see Chapter 9), which dictate a separate research agenda (Landres et al. 1988). Despite conceptual and practical problems, the indicator approach is firmly established in tradition and law. Landres et al. (1988) made a number of recommendations to increase the rigor and effectiveness of the use of indicator species. In the context of monitoring forest ecosystems, the goal will be to equate changes in the relative abundance or presence/absence of some birds and small mammals to habitat changes and how that relates to the overall condition of a forest. However, population changes in wildlife are due to a number of factors. Habitat characteristics (quality, abundance, and distribution across a landscape) are only one set of such factors. Others influencing wildlife populations include competitive interactions, disease, predation, and intrinsic cyclic-like phenomena. Many of these factors often interact. The complexities of wildlife population dynamics suggest other demographic variables such as productivity —that is, young produced per female—should also be monitored (Van Horne 1983, Temple and Weins 1989). However, this was suggested as being too costly for EMAP.

Birds and salmon present a problem. Many species of birds are seasonal migrants, and all salmon migrate to and from the ocean. For migratory birds, it will be very difficult to determine if habitat conditions on the breeding or wintering grounds are responsible for population changes by simply assessing the relative abundance of those species. In addition, productivity of migrants could be influenced by conditions on both ranges. For example, the use of DDT in Central and South America may result in decreased productivity of migrants independent of conditions in North America. Because of this, assessing migratory birds only while in North America may not reflect ecosystem conditions. But the opportunity to collect valuable data on neotropical migrants during other surveys at little additional cost needs to be considered.

Salmon are currently the focus of much attention in the Northwest, and require comprehensive assessments of their abundance in relation to not only spawning and rearing habitat, but also their transportation through or around hydropower generation facilities, the harvest of adult salmon by commercial and sport fishing as well as predation by other animals, and the effect of supplementing wild salmon with hatchery fish. Hatchery supplementation is an attempt to overcome what appeared to be declines in relative abundance of adult spawning fish from the other factors.

According to a timber industry association in the state of Washington, development and implementation of a landscape management system for the protection of wildlife and the habitat upon which they depend will involve: [1] coordination of land use activities among a multitude of local and state jurisdictions; [2] clear definition of the roles and responsibilities of private landowners and public land management and regulatory agencies; [3] revisions to existing rules and regulations; and [4] elimination of the need to manage wildlife using the species-by-species approach (Washington Forest Protection Association 1993). Landscape management is one approach to managing healthy and sustainable forest ecosystems. Coordinating land use activities among different agencies and ownerships is mind-bogglingly complex, and dependent on a fundamental consensus about the role of forests in society that will be difficult to achieve (J. Freemuth, review comments).

Ecosystem Management

Forest health is closely related to ecosystem management because both involve the quest to provide sustainable ecosystems. Successful ecosystem management strategies will promote healthy forest conditions at the landscape level.

Oliver (1992) addressed the needs for implementing ecosystem management across a landscape of ownerships:

> Systems need to be developed that would plan and manage silvicultural operations to maintain a target balance of stand structures across a landscape. Creative incentives, regulations, and approaches are needed to make a transition from the current direction to the goal of managing for a variety of structures across the landscape for biodiversity, high-quality timber, and rural community productivity.

This is a large agenda for researchers, managers, and policymakers.

Everett et al. (1993) said ecosystem management requires a theoretical basis for ecosystem analysis and description, information on current forest conditions, and ecological reference points that describe potentially sustainable conditions. Ecosystem management integrates societal values and expectations, ecological potentials, and economic considerations. Although rapid progress has been made in landscape ecology and conservation biology, much development and testing is required to provide a solid basis for management (Everett et al. 1993).

According to Brooks and Grant (1992), the difference from previous forest management science is attention to issues at larger spatial scales, and with explicit recognition of the need for interdisciplinary approaches. Only by considering groups of stands (landscapes and regions) can biological diversity, habitat and hydrological impact, and interaction with human communities be addressed (Brooks and Grant 1992).

No approach has been found for evaluating the full range of values for the bundle of goods and services expected from ecosystem management. This shortcoming has at least two important implications (Everett et al. 1993):

- In spite of what society values, costs and benefits for most of the goods and services that can be derived from ecosystem management may be quantified either directly or indirectly in terms of timber values.
- Efforts to develop greater specificity for values will require more explicit notions of ecosystem outputs—both amounts and timing. Part of the issue is that it is essential to explicitly link what is valued to the measured outputs.

If the USDA Forest Service continues to express values of goods and service in terms of timber values, as in bullet one above, public trust will likely be foreclosed (J. Freemuth, M. Brunson; review comments). Thus it is important to determine what society expects and desires from its resource base.

Quantification should not be done "in spite of what society values," but because society values a range of forest benefits. The values of timber foregone to provide other benefits (or "opportunity costs") are fairly easy to quantify, and provide a useful indicator of the value of other benefits. Opportunity costs can help the public and policymakers arrive at decisions on a range of forest outputs.

Historic range of variability and desired future conditions. Historic ranges of variability are reference points, not recipes (Everett et al. 1993). Everett (review comments) said several points in time need to be sampled, and at several spatial scales to develop a reliable picture of past conditions and disturbance events and effects that created current conditions. Landscape-level conditions other than current or historic ones may be sustainable and better able to meet public expectations. However, we lack information on the sustainability of states other than historic and current, and need to view them as experimental (R. Everett, review comments). They provide a baseline for judging current conditions of ecosystem elements, and will therefore be useful in assessing forest health (see Chapter 10 for full discussion).

According to Brooks and Grant (1992), research cannot define social objectives for forests, but it can help evaluate the ecological, social, and economic tradeoffs between alternative visions. They proposed a research agenda for describing the essential features of possible future conditions. It is within those possible outcomes that desired futures need to be considered. This scientific approach has six broad objectives, each of which Brooks and Grant (1992) described in more detail:

[1] Define, characterize, and measure different forest ecosystem states;

[2] Develop methods to analyze stocks and flows associated with different ecosystem states;

[3] Evaluate social benefits, values, costs, and preferences associated with different states, stocks, and flows;

[4] Determine factors that influence transitions between states;

[5] Develop scenarios and analyze associated changes in states, stocks, and flows; and

[6] Propose methods of public participation in defining objectives and in designing and implementing forest demonstration and research areas.

Consistent with point [6] above, social scientists will need to develop additional knowledge about societal values and expectations associated with resource management. This will be particularly important in designing and implementing ecosystem management strategies. Some people will expect to see some evidence that new management approaches will reduce risks and uncertainties (M. Brunson, review comments). Some people want to participate in the design of public participation forums and the determination of values. They do not want their desires reduced to numbers by experts who then are likely to want to speak for them (J. Freemuth, review comments).

Is the science adequate? At present, the science of ecosystem management is not adequate to determine what the desired state of a forest ecosystem is. Additional ecological and social science research is necessary.

Everett et al. (1993) said there are numerous alternative states for ecosystems; some conserve site productivity and biological diversity, while others clearly forfeit future options. A conservative approach would maintain ecosystem structures and processes within historical ranges of variability by mimicking the effects of disturbances that maintained this range of vegetation patterns. Historical landscape patterns may not meet society's current or future expectations, and other states may be prescribed that better meet expectations, but there is no information available as to their potential sustainability. Given current ignorance and poor success with landscape designs different from historical conditions, it is prudent to validate the sustainability of other states first before they are widely prescribed (Everett et al. 1993).

Land managers, according to Everett et al. (1993), are currently limited in their prescriptions for healthy and sustainable ecosystems because they lack an adequate inventory and characterization of current landscape conditions, societal expectations are as yet poorly understood, and sustainable landscape conditions to use as a target have not been articulated for each landscape. The following needs are apparent (Everett et al. 1993):

- A comprehensive inventory and classification of terrestrial and aquatic ecosystems are needed. Ecological landscape units and stream classification units should be identified and characterized; these units are the building blocks of an hierarchial approach to ecosystem management.
- The historical ranges of conditions of landscape and stream units and their historical disturbance regimes should be quantified.
- Significant differences in tactics and outcomes are associated with implementation of endangered species conservation strategies. Conservation strategy for one or several species may be in conflict with sustainability of other species, structures, or processes of ecosystems. Remedies to conflicts should be sought now.
- Early-warning monitoring systems are needed to alert land managers to potential hazards to diversity, productivity, or resource sustainability.
- Monitoring standards and techniques are needed to evaluate landscape management projects. Monitoring should ensure that landscape management projects were implemented as designed, that they were acceptably effective, and that landscape management experimental hypotheses are validated or invalidated.

Because ecosystem management seeks to sustain desired forest conditions, it involves the full range of forest health concerns. As we said at the beginning of this section, ecosystem management presents a large agenda for landscape ecologists, biologists, forest scientists, social scientists, land and resource managers, and policymakers. That agenda includes descriptions of historical conditions, comprehensive inventories, and determination of societal goals in both ecological and economic dimensions.

National Forest Planning and Management

The National Forest Products Association (1992) stated that forest health, like all management concerns on national forests, is best addressed through forest planning. Proactive forest management aimed at enhancing forest health must occur through a free exchange of ideas. In 1976, the U.S. Congress directed a planning process under the National Forest Management Act which envisioned public participation to help guide management of our National Forests. Forest planning can resolve the difficult trade-offs faced by forest users who expect forest health improvements on our National Forests. According to the forest industry, the planning process should be utilized to resolve these problems (National Forest Products Association 1992). However, the forest planning process will have to deal with forest health concerns more explicitly than it has in the past. As the analysis in Chapter 14 and case study in Chapter 16 pointed out, there is an urgency about forest health conditions, whether drought conditions are involved or not. The forest planning process may be too inflexible to cope with forest restoration following large scale insect and disease epidemics or wildfires.

Because national forests are such an important component of Idaho's forest resource, ecosystem management promises to be an important determinant of forest conditions in Idaho. The approach of ecosystem management, in the words of the Chief of the Forest Service (Robertson 1992), is a way to "blend the needs of people and environmental values" to maintain "healthy, productive, and sustainable ecosystems." To accomplish this goal, the Chief suggested three areas of attention: [1] a new "higher level of dialogue" with the American people, [2] expanded partnerships, and [3] increased cooperation between scientists and land managers to close the gap between new science and its application (Gray 1992a). Elaboration on each of these points follows.

[1] It will take what Chief Robertson called a "higher level of dialogue" to determine desired future forest conditions. There is little guidance from the Forest Service on what form this "higher level" might take, nor how to achieve it. If ecosystem management is to work, these must be large-scale land-based representations of what states of ecosystems should be maintained across the landscape. In other words, big maps with lines drawn on them, creating zones. Resource output targets can then be identified within the ecological capability of these zones, taking into account the fact that ecosystems exist over long time periods in different states or stages of succession. If management actions are to mimic nature, then it will not be possible to say that any given acre will remain in a certain ecosystem stage, such as old-growth. However, at the landscape-level scale of, for example one million acres, it would be possible to say that some percentage of that area within an ecological zone would be in an old-growth condition at any given period in the future. The actual acres would move across the landscape over a long period of time.

[2] Partnerships will be necessary to plan management across ownership boundaries, as will be necessary under landscape management. The importance of this point cannot be overemphasized. Partnerships depend on public trust, and are a way to restore public trust.

[3] There are many ways to characterize the need for closer coordination of research and management. The need for integrated inventories is certainly one. Another can be illustrated by this Associated Press (1993b) statement: "Officials said the Idaho Panhandle management plan needs significant changes to combat deteriorating watersheds and extensive root rot." These are management problems that could benefit from some attention by researchers. An implication is that the Research branch of the USDA Forest Service might need to be linked more directly to management of the National Forest System.

Conclusions

To prevent unhealthy forest conditions and restore desired forest conditions, open dialogue between forest managers, researchers, and the public is necessary. Forest health provides a common thread that relates today's forest management problems to something everyone can understand. The communication potential is strong even if the forest health analogy is imperfect.

Most everyone recognizes that serious forest management problems exist in the Inland West. The causes of these problems are known, as are the solutions to some of the problems. Two major barriers seem to stand in the way of restoring healthy conditions that will promote sustainable forest ecosystems while providing for human needs. Those two things are public policies and public trust.

Public agencies are responsible for managing more than two-thirds of Idaho's forests, and a majority of forests in the Inland West. Most of these forests are in the National Forest System administered by the USDA Forest Service under the National Forest Management Act of 1976. The mandated planning process is perhaps too inflexible to treat the effects of insect and disease epidemics and catastrophic wildfires. A policy solution may be necessary to add flexibility. Forest restoration and actions to prevent future problems will be expensive and require some source of funds that are not currently available in National Forest System budgets.

Public trust is, of course, an important issue that is intertwined with management of public forests, especially national forests. Everyone owns these forests and is, by law, entitled to participate in planning how these forests will be managed. The history of implementing the National Forest Management Act of 1976 makes one thing clear: without public trust, public resource managers will spend most of their precious personnel and budget resources producing planning, environmental analysis, and administrative appeal documents. How these documents relate to sustainable ecosystems is an important but moot point. The agencies do the paperwork because segments of the public have lost faith in their ability to resolve the conflicting desires that people express. The only way out of this dilemma is to build trust by open dialogue and partnerships.

Then and only then will agencies be able to implement management strategies and actions. We have some of the solutions to problems associated with forest health management in the broad ecosystem context, but not all of them. Conclusions on future directions are as follows:

- The two major barriers to implementing what is known about forest health management are public policy and public trust. They are interrelated.
- Partnerships between managers, scientists, and the public are a necessary component of an effective forest health management strategy.
- Tried and proven silvicultural tools can be used to improve forest health.
- Adaptive management is an effective strategy when faced with change and uncertainty, which are inevitable.
- Salvage logging is useful for reducing hazardous fuel levels to protect remaining vegetation and soils and recovering economic values, but needs to be conducted under ecologically and socially acceptable guidelines, which need to be developed with additional site-specific research.
- Research efforts focused on development of hazard and risk rating systems would be useful to guide managers in determining which stands need the most attention, and what should be done to ensure sustainable forest ecosystems.
- The National Forest Management Act planning processes have not adequately considered the impacts of insect, disease, and wildfire outbreaks in Idaho and the actions necessary to sustain forest health and long-term productivity.
- The forestry profession is currently undergoing substantial changes. Developing new planning approaches and management strategies to embark on the future direction of sustaining the full range of forest

ecosystem values desired by society is a paramount concern. These changes need the support of forestry professionals and forest owners, including the public that owns two-thirds of Idaho's forests.

- Forests are in decline in Idaho, and because of the diverse nature of these forests, there is no single causal variable, and thus no easy fix. Forest health is an integrating concept whereby scientists from different backgrounds can work together to develop knowledge in support of management directions that will sustain ecosystems while providing for the full range of forest values society desires.

- The research agenda includes silviculture, hazard rating and risk analysis, integrated inventories, and modeling. Special attention needs to be given to wildlife as indicators of forest ecosystem health.

- Ecosystem management is a broader concept than forest health, but includes forest health. Much work still needs to be done to develop and implement the ecosystem management concept, especially in the social dimension. In the end, only when forests are viewed from the larger landscape perspective that ecosystem management promises can multiple use be considered a feasible strategy.

Exploring the Definition of Forest Health

Presented at a Symposium on Forest Health in the Inland West
by Jay O'Laughlin (1993), June 1993, Boise, Idaho

The dictionary (Random House 1971) provides four definitions of health. All but one definition of health applies to the general condition of the human body and mind. The fourth and broadest definition of health is simply "vigor; vitality: *economic health.*" If an economy can be described as healthy, surely a forest can, too (emphasis added by underlining).

The following quotations are state-of-the-art definitions of forest ecosystem health. The listing illustrates how the concept has developed chronologically. Forest health, health, or ecosystem health are emphasized by underlining.

The conclusion [regarding "The Health of the Forests"] can be briefly expressed. The function of forestry is to produce not just crops of timber, but crops of healthy timber. Forest pathology in its relation to forestry shares an interest and responsibility towards this objective in all that is comprised under the appellation "healthy" (Faull 1930).

A land ethic, then, reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land. Health is the capacity of the land for self-renewal. Conservation is our effort to understand and preserve this capacity (Leopold 1949a). A science of land health needs, first of all, a base datum of normality, a picture of how healthy land maintains itself as an organism (Leopold 1949b).

[M]ost forest ecosystems lead long, productive lives.... [I]nflictions of old age, environmental stress, or unwelcomed visitors produce unhealthy ecosystems.... In recognizing that forests and other ecological systems provide irreplaceable services, when these systems are threatened, we must administer aid (Waring 1980).

[T]he effects of regional and global air pollution on forest ecosystem health are difficult to quantify.... Sensitive and practical methods must be developed and implemented in order to monitor and predict forest health (Smith 1985).

The phrase *ecologically healthy* refers to the functions affecting biodiversity, productivity, biogeochemical cycles, and evolutionary processes that are adapted to the climatic and geological conditions in the region (Karr et al. 1986).

In the search for the causes of pine growth reduction [in the Southeast], all hypotheses need testing, and all aspects of forest health need monitoring (Sheffield and Cost 1987).

A desired state of forest health is a condition where biotic and abiotic influences on the forest (i.e., insects, diseases, atmospheric deposition, silvicultural treatments, harvesting practices) do not threaten management objectives for a given forest unit now or in the future. Forest health is a complex subject with both real and perceived problems which can arouse strong emotions. Such problems justify nationwide concern. The actual problems are the product of events occurring over a long period of time. The perceived problems reflect an incomplete understanding of forest ecosystems, the biological processes operating within them, and alternative views of the purposes to be served by the forest (USDA Forest Service 1988).

No widely accepted definition of forest health exists (Riitters et al. 1990).

The public perception of a healthy forest as one that can recover from insect infestation, disease, and other natural factors is one component of the "sustainability" value. But a term such as sustainability can have different meanings in the scientific community, and therefore it is difficult to determine what to measure.... Individuals will always have different perceptions of forests, and thus of how to describe their condition. For now, analysts must be sensitive to these differences; ultimately, we may be able to identify a set of values that relates to everyone's perceptions of forests (Riitters et al. 1990).

Definitions are critical in any assessment of forest health.... Tree or forest decline is a wide-spread decrease in the health and vigor of a forest tree or groups of trees, respectively, due to disease or injury.... Until we become serious about long-term forest health assessment, we will not know whether the health of forest systems is improving, stable, or declining (Smith 1990).

[U]nderstanding ecosystems ... will provide the scientific basis for addressing health and productivity issues (USDA Forest Service, Sesco 1992).

Forest health is the condition of the forest based on diversity of natural features of the landscape, distribution of plant communities exhibiting various stages of succession, and the degree to which naturally occurring fauna occupy habitats that are varied and equitably distributed across the landscape (USDA Forest Service, Gast et al. 1991).

Resilience is the ability of an ecosystem to absorb change without major loss of function. Sites vary in their natural resilience. The maintenance of long-term productivity correlates strongly to ecosystem resilience. An important way to reduce loss of resilience is to manage for biological diversity; i.e., diversity of species, successional stages, and openings across the landscape. This will help retain the functional relationships that lead to resilience in the first place. We are a long way from full understanding of the resilience of forest ecosystems (USDA Forest Service, Gast et al. 1991).

A 'healthy ecosystem' is one in which the physical, chemical, and biological mechanisms of ecosystem recovery are operating at rates that are characteristic of that ecosystem.... The individual/ecosystem analogy is imperfect, however. Ecosystems do not die in the sense that an individual organism dies. Ecosystems will always recover either partially or completely from even severe disturbance if the processes of recovery are permitted to operate (Kimmins 1992).

Ecosystem health is a normative concept: a bottom line. It represents a desired endpoint of environmental management, but the concept has been difficult to use because of the complex, hierarchical nature of ecosystems. Without an adequate operational definition of the desired endpoint, effective management is unlikely.... [T]he concept of ecosystem health is a comprehensive, multiscale, dynamic, hierarchial measure of system resilience, organization, and vigor. These concepts are embodied in the term 'sustainability,' which implies the system's ability to maintain its structure (organization) and function (vigor) over time in the face of external stress (resilience). A healthy system must also be defined in light of both its context (the larger system of which it is part) and its components (the smaller systems that make it up) (Costanza 1992).

Since fast-changing human cultures are embedded in larger-scale, slow-changing ecological systems, we must develop policies that allow human cultures to thrive without changing the life support functions, diversity, and complexity of ecological systems.... Defining ecosystem health is a process involving the identification of important indicators of health (such as a species or a group of species), the identification of important endpoints of health (such as relative stability and creativity), and, finally, the identification of a healthy state incorporating our values.... The workshop participants arrived at a working definition of ecosystem health that incorporates most of the considerations just listed. It defines health in terms of four major characteristics applicable to any complex system: *sustainability*, which is a function of *activity, organization,* and *resilience*. Thus they concluded: "An ecological system is healthy and free from 'distress syndrome' if it is stable and sustainable—that is, if it is active and maintains its organization and autonomy over time and is resilient to stress" (Haskell et al. 1992).

In the ecological realm, one generally confers the connotation of "health" to a state of nature (whether managed or pristine) that is characterized by systems integrity: that is, a healthy nature exhibits certain fundamental properties, of self-organizing complex systems.... [W]hat is "desired" or "healthy" must also take into account social and cultural as well as ecological values. These values may differ markedly among various segments of society. Native peoples, for example, value the integrity of the forest as a "cultural home," one that permits the survival of traditional ways of gathering food, spiritual life, and the like. Foresters value forests quite naturally in terms of its productivity of merchantable timber. Consequently, the health status of forested ecosystems transformed through harvesting and other means will be assessed in very different ways depending on cultural and social values (Rapport 1992b).

How can we create a practical definition of system health? First, an adequate definition of ecosystem health should ... be a combined measure of system resilience, balance, organization (diversity), and vigor (metabolism). Second, the definition should be a comprehensive description of the system. Looking at only one part of the system implicitly gives the remaining parts zero weight. Third, the definition will require the use of weighting factors to compare and aggregate different components in the system.... And fourth, the definition should be hierarchial to account for the interdependence of various time and space scales (Costanza 1992).

By ecosystem management, we mean that an ecological approach will be used to achieve the multiple-use management of the National Forests and Grasslands. It means we must blend the needs of people and environmental values in such a way that the National Forests and Grasslands represent diverse, healthy, productive, and sustainable ecosystems (USDA Forest Service, Robertson 1992).

'Forest health' has become a buzzword among timber state lawmakers, but the sound grates on the ears of environmentalists like a chain saw. Francis Hunt, lobbyist with the National Wildlife Federation, described forest health "as nothing more than a thinly veiled attempt by industry to increase the timber cut and weaken environmental laws" (Swisher 1992).

The vast majority of residents (85%) consider insect infestations and disease in Idaho forests a problem, most of which feel it is a serious problem. In fact, only 5% of respondents say insect infestations and disease in the forests is not at all a problem (Dan Jones and Associates 1992).

The heart of an ecologically healthy watershed is the riparian forest (Naiman et al. 1992).

Forest health can be defined as the ability of a forest to recover from natural and human-caused stressors.... Over time, single or multiple stressors may alter trees to a point where they can no longer recover and begin to "decline," exhibiting crown dieback and deterioration. This decline may be reflected by changes in rates of succession, forest composition and structure, or general productivity. Large outbreaks of insects and disease do not automatically indicate a deterioration in forest health.... It is desirable to establish and maintain forests that are as resilient as possible to natural and human-caused stressors, while meeting the values, needs, and expectations of society (USDA Forest Service 1993a).

How to sustain the health of forest ecosystems has emerged as a key challenge for the forestry profession, along with the traditional (but no less profound) questions about how to provide for the production, use, and enjoyment of forest resources.... Forest health is a particularly complex topic.... Forest health is reflected in how the forest responds or is able to respond to stress.... Forests can be considered healthy when there is an appropriate balance between growth and mortality... Having the resilience to react and overcome various stressors is a key indicator of health, and is a key objective of ecosystem management.... [E]cosystem management is an ecological approach to forest resources management. It attempts to maintain the complex processes, pathways, and interdependencies of forest ecosystems and keep them functioning well over long periods of time, in order to provide resilience to short-term stress and adaptation to long-term change. Thus, the condition of the forest landscape is the dominant focus, and the sustained yield of products and services is provided within this context (Society of American Foresters, Norris et al. 1993).

Ecosystem management ... rests on six principles. [The first is] sustainability. Restore and maintain diversity, health, and productivity of forest and grasslands. Provide commodities and uses consistent with sustained vitality and resiliency of ecological systems (USDA Forest Service 1993b).

Managing for healthy ecosystems will promote biological diversity and sustainable development (USDI Bureau of Land Management 1993).

Ecosystem management is in vogue. It's a new means of natural resource management. I concur and I applaud that move because addressing one species at a time is leading us both to an exhaustion of patience and resources. However, that approach is not going to be simple, it's not going to be cheap. One of my heroes said, "Ecosystems are not only more complex than we think, they're more complex than we can think" (Thomas 1993).

Regardless of what we are doing, our efforts [to resolve the "logjam" or gridlock in the forests of the Pacific Northwest] must be guided, it seems to me, by five fundamental principles. First, we must never forget the human and the economic dimensions of these problems. Where sound management policies can *preserve the health of forest lands*, sales should go forward. Where this requirement cannot be met, we need to do our best to offer new economic opportunities for year-round, high-wage, high-skill jobs. Second, as we craft a plan, we need to *protect the long-term health of our forests, our wildlife and our waterways*. They are, as the last speaker [Ted Strong, Columbia River Inter-Tribal Fisheries Commission] said, a gift from God and we hold them in trust for future generations. Third, our efforts must be, insofar as we are wise enough to know it, scientifically sound, ecologically credible and legally responsible. Fourth, the plan should produce a predictable and sustainable level of timber sales and non-timber resources that will not degrade or destroy our forest environment. And fifth, to achieve these goals, we will do our best, as I said, to make the federal government work together and work for you (*Clinton 1993*, emphasis added).

SUSTAINING ECOLOGICAL SYSTEMS: GOALS - Caring for the land by sustaining healthy ecosystems. CONCEPTS: HEALTH - An ecosystem is healthy if it maintains its complexity and capacity for self-organization (resiliency) (USDA Forest Service 1993c).

[end of material from O'Laughlin 1993]

Forest Health is a term defining the relative capacity of a
forest to sustain values while maintaining integrity as a system,
without human intervention

1. "Health" is an anthropomorphic term, therefore we have difficulty in including dead and dying trees, insect and disease activity, competitive stress, in a "healthy forest," and yet the term must accommodate a forest with some level of these attributes.

2. The concept of "value" is important in defining health, because we need to identify healthiness relative to some standard. In humans, healthiness is defined in terms of appearance, function, and capacity to perform. Similarly, a healthy forest must have the general appearance of vitality, function as a system, and produce values of aesthetics, watershed protection, wood, wildlife habitat, etc., without permanent deterioration.

3. "Healthiness" must not require sustained human intervention in terms of fertilization, herbicides, and other management inputs.

4. The concept of healthiness is influenced by the dual problems of spatial and temporal issues. A healthy forest will contain individual stands, trees, shrubs, and other organisms that might not be "healthy". Similarly, forests, stands, or trees might not be "healthy" at some point in time in an analogous way that an otherwise healthy person might have a cold or headache.

5. A healthy forest must include one that can, at some point, be harvested. A harvested site must be considered healthy if it is capable of returning to a forested condition without permanent loss of productivity.

6. Healthy forests must include monocultures as well as mixed stands, because there are examples of both in nature that have been sustained for millennia.

All these concerns must be accommodated within a definition of a **Healthy Forest**.

John A. Helms (1993)
Professor of Silviculture
University of California, Berkeley

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GLOSSARY

(Note: terms in **boldface** are defined elsewhere in the Glossary.)

Adaptive forestry. The University of Idaho term for forest management, the principal concept of which is **ecosystem sustainability**. A dominant characteristic is diversity: **landscape** diversity from the variety and distriburtion of management practices across the land and diversity of **ecosystem structure** of canopy layers and species variety in individual forest units. Such diversity fosters full **ecosystem function** (Adams 1992).

Adaptive management. Establishing measurable objectives, using the best knowledge to prescribe practices, monitoring the results, and adjusting practices as needed to meet objectives (Norris et al. 1993).

Allowable sale quantity (ASQ). The quantity of timber that may be sold from an area of suitable land covered by a **Forest Plan**, for a time period specified by the Plan. This quantity is usually expressed as the "average annual allowable sale quantity" (Gast et al. 1991).

Annual mortality. The volume of sound wood in trees that died from natural causes during a specified year (USDA Forest Service 1990b).

Annual removals. The net volume of trees removed from the inventory during a specified year by harvesting, cultural operations such as timber stand improvement, land clearings, or changes in land use (USDA Forest Service 1990b).

Balance of nature. Generally speaking, the balance of nature includes three ideas: [1] nature undisturbed is constant; [2] when disturbed but released from that disturbance nature returns to its original, constant condition; [3] that constant condition of nature is good and desirable. It has also been used to refer to the idea of a great chain of being, that is, every creature having its place in the harmonious workings of nature and well adapted to its purpose (Botkin 1990).

Basal area. The area of a cross-section of a tree stem, generally at **breast height** and inclusive of bark (SAF 1983).

Breast height. On standing trees, a standard height from ground level for recording diameter, girth, or **basal area**; a convenient height at 4 feet 6 inches for girth-tape readings (SAF 1983).

Catastrophic pest-caused damage (losses). A level of insect- or disease-caused tree **mortality** and/or damage, such that resource management goals or objectives are significantly hindered, and **Desired Future Condition** described in **Forest Plans** cannot be achieved in either the short-term or the long-term (Gast et al. 1991).

Climax. The culminating stage in plant **succession** for a given site where the vegetation has reached a highly stable condition, and is capable of reproducing in competition and persisting without disturbing influence (Gast et al. 1991).

Climax species. Those species that dominate a forest **stand** in either numbers per unit area or biomass at **climax** (Gast et al. 1991).

Complexity, ecosystem. As part of the **forest health** definition, includes spatial and temporal scales; that is, differences attributable to different space and time considerations.

Desired Future Condition. 1. A term used to reflect the hoped-for results to be achieved through the implementation of the **Forest Plans** in both the short- and long-term (Gast et al. 1991). 2. A deliberated outcome for a **landscape** that will sustain ecological conditions and meet human needs, now and in the future (USDA Forest Service 1993b).

Diameter class. A classification of trees based on diameter outside bark measured at **breast height.** When using 2-inch diameter classes, the 6-inch class, for example, includes trees 5.0 through 6.9 inches dbh (USDA Forest Service 1990b).

Drought. A moisture unbalance which occurs when loss of water through foliage exceeds uptake of water. It may arise from one or more of the following: Inadequate soil moisture, excessive transpiration, restrictive rooting, or deficient root activity (Gast et al. 1991). See also the discussion and definition in the "Precipitation trends" section of Chapter 14.

Ecological health. Both the occurrence of certain attributes that are deemed to be present in a healthy, **sustainable** resource, and the absence of conditions that result from known stresses or problems affecting the resource (Palmer et al. 1992, after Rapport 1989).

Ecoregion. An area (region) of relative homogeneity in ecological systems (Gallant et al. 1989). Climate and vegetation type are characteristics used to differentiate these areas (Palmer et al. 1992).

Ecosystem. 1. An interacting system of organisms considered together with their environment; e.g., marshes, watersheds, and lakes are ecosystems (Gast et al. 1991). 2. Any complex of living organisms with their environment, that we isolate mentally for the purposes of study (SAF 1983). 3. A set of interacting species and their local, nonbiological environment, functioning together to sustain life (Botkin 1990). 4. A complex of interacting subsystems which persists through time due to the interactions of its components (Reichle et al. 1975). 5. A local complex of interacting plants, animals, and their physical surroundings which is generally isolated from adjacent systems by some boundary, across which energy and matter move; examples include a **watershed**, an **ecoregion**, or a biome (Palmer et al. 1992). See also **complexity, ecosystem.**

Ecosystem function. Attributes of the rate of change of structural components of an ecosystem; examples include primary productivity, denitrification rates, and species fecundity rates (Palmer et al. 1992). See also **ecosystem structure.**

Ecosystem management. 1. "By ecosystem management, we mean that an ecological approach will be used to achieve the multiple-use management of the National Forests and Grasslands. It means that we must blend the needs of people and environmental values in such a way that the National Forests and Grasslands represent diverse, healthy, productive, and **sustainable ecosystems**" (Dale Robertson 1992, Chief of the USDA Forest Service). 2. "We're still defining what ecosystem management consists of. But most importantly, the Pacific Northwest is serving as a laboratory to see how ecosystem management might be implemented" (Jim Lyons, 1993, Assistant Secretary of Agriculture for Natural Resources and Environment; see Hopps 1993). 3. The five volume set of documents called the "Eastside Forest Ecosystem Health Assessment" issued by the USDA Forest Service in mid-1993 (see Everett et al. 1993) contained three definitions of ecosystem management:

(a) The careful and skillful use of ecological, economic, social, and managerial principles in managing ecosystems to produce, restore, or **sustain** ecosystem integrity and desired conditions, uses, products, values, and services over the long term (Volume II - Ecosystem Management, Principles and Applications).

(b) The conservation and use of natural resources to maintain biological diversity, long-term site productivity, and **sustainable** resource production and use; the new management paradigm on National Forests (Volume III - Assessment).

(c) A system of making, implementing, and evaluating decisions based on the ecosystems approach, which recognizes that ecosystems and society are always changing (Volume V - A Broad, Strategic Framework for Sustainable-Ecosystem Management).

Ecosystem structure. Attributes of the instantaneous state of an **ecosystem**; examples include species population density, species richness or evenness, and standing crop biomass (Palmer et al. 1992).

Endemic. 1. Restricted to, and constantly present in, a particular locality (Gast et al. 1991). 2. Of an organism confined, in its indigenous occurrence, to a particular region. 3. Applied to populations of potentially injurious plants, animals or viruses that are at their normal, balanced level, in contrast to **epidemic** (SAF 1983).

Endpoint (of ecological health assessment). A quantitative or quantifiable expression of the environmental value being considered in the environmental analysis; examples include a 25% reduction in gamefish biomass or local extinction of an avian species (Suter 1990, cited in Palmer et al. 1992).

Epidemic. 1. Prevalent and spreading rapidly; widespread. Often used in reference to a rapidly increasing and spreading population of insects (Gast et al. 1991). 2. Of populations of plants, animals, and viruses that build up, often rapidly to lightly abnormal and generally injurious levels (SAF 1983). Contrasts with **endemic**.

Extensive forestry. The practice of **forestry** on a basis of low operating and investment costs per acre (SAF 1983). Contrasts with **intensive forestry**.

Forest health. 1. No widely accepted definition exists (Riitters et al. 1990). 2. A condition of forest **ecosystems** that **sustains** their **complexity** while providing for human needs (see Chapter 5).

Forest land. Land at least 10% stocked by forest trees of any size (USDA Forest Service 1990b).

Forest management. 1. Generally, the practical application of scientific, economic and social principles to the administration and working of a forest estate for specified objectives. 2. More particularly, that brach of **forestry** concerned (a) with the over-all administrative, economic, legal and social aspects, and (b) with the essentially scientific and technical aspects, especially **silviculture**, **forest protection** and forest regulation (SAF 1983).

Forest Plan. (See **National Forest Land and Resource Management Plan**).

Forest protection. That branch of **forestry** concerned with the prevention and control of damage to forests arising mainly from the action of man (particularly unauthorized fire, grazing and browsing, felling, fumes, and smoke) and of pests and pathogens, but also from storm, frost, and other climatic agencies (SAF 1983). Note that wildfire is excluded from the definition. Those activities are termed fire pre-suppression, suppression, or prevention, or in the case of fuels, treatment to reduce fire threat or spread, fire **hazard** reduction (SAF 1983).

Forest type. A classification of forest land based upon the species presently forming a plurality of the live-tree **stocking** (USDA Forest Service 1990b).

Forestry. The science, the art and the practice of managing and using for human benefit the natural resources that occur on and in association with forest lands (SAF 1983, this definition was adopted by the Society of American Foresters in 1967).

Growing stock. A classification of timber inventory that includes live trees of commercial species meeting specified standards of quality or vigor. Cull trees are excluded. When associated with volume, includes only trees 5.0-inches dbh [**diameter class**] and larger (USDA Forest Service 1990b).

Habitat type. An aggregation of units of land capable of producing similar plant communities at **climax** (SAF 1983).

Hazard. 1. A state that may result in an undesired event; the cause of **risk** (Palmer et al. 1992). 2. Probability of tree **mortality** or damage by an insect or disease (Gast et al. 1991). 3. In fire prevention—the objective of which is to reduce the number of human-caused fires—it is the material or fuel that will ignite or burn (Barney et al. 1984). See also **forest protection.**

Health. See **ecological health** and **forest health.**

Indicator. A characteristic of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to the stressor, or degree of ecological response to the exposure (Palmer et al. 1992).

Intensive forestry. The practice of **forestry** so as to obtain a high level of volume and quantity of output per unit of area, through the application of the best techniques of **silviculture** and management (SAF 1983). Contrasts with **extensive forestry.**

Landscape. 1. The fundamental traits of a specific geographic area, including its biological composition, physical environment, and anthropogenic or social patterns (Palmer et al. 1992). 2. A diverse land area of biological communities and physical features interacting with one another (Washington Forest Protection Association 1993). 3. At the landscape level, a size of 100,000 to 1,000,000 acres in suggested for perspective, but this point requires discussion and resolution within the forestry profession (Norris et al. 1993).

Landscape ecology. The study of the distribution patterns of communities and **ecosystems,** the ecological processes that affect those patterns, and changes in pattern and process over time (Forman and Godron 1986).

Long-term productivity. The capability of the land to support sound **ecosystems** which produce resources such as forage, timber, wildlife, and water (Gast et al. 1991).

Monitoring. A process used to collect significant data from defined sources to identify departures or deviations from expected **Forest Plan** outputs (Gast et al. 1991).

Mortality. The net volume of **growing-stock** trees that have died from natural causes during a specified period (Benson et al. 1987). See also **annual mortality.**

National Environmental Policy Act (NEPA 1969). An act of Congress directed to declare a national policy which will encourage productive and enjoyable harmony between humans and their environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of humans; to enrich the understanding of ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality (Gast et al. 1991).

National Forest Land and Resource Management Plan. A Plan which "... shall provide for multiple use and **sustained yield** of goods and services from the National Forest System in a way that maximizes long-term net public benefits in an environmentally sound manner" (Gast et al. 1991). Forest Plans are required by the **National Forest Management Act.**

National Forest Management Act (NFMA 1976). A law passed in 1976 as an amendment to the Forest and Rangeland Renewable Resources Planning Act, requiring the development of Regional Guides and **Forest Plans** and the preparation of regulations to guide that development (Gast et al. 1991).

Nature. Has been used to mean (1) the natural world on the Earth as it exists without human beings or civilization, that is, the environment including mountains, plains, rivers, lakes, oceans, air, rocks along with all nonhuman, nondomesticated living things; and (2) the universe, with all its phenomena, including the objects and the forces in the universe (Botkin 1990).

Net annual growth. The net increase in the volume of trees during a specified year. Components include the increment in net volume of trees at the beginning of the specific year surviving to its end, plus the net volume of trees reaching the minimum size class during the year, minus the volume of trees that died during the year, and minus the net volume of trees that became cull trees during the year (USDA Forest Service 1990b).

Old-growth forest. A forest condition defined by age-class of vegetation, structure of forest canopy, volume of dead and downed wood debris, and other attributes; old-growth is trees, other vegetation, birds, mammals, and other organisms and the manner in which they associate and interact in communities. No single measurement, such as age, is sufficient to describe it (Franklin et al. 1981).

Other forest land. **Forest land** other than **timberland** and **reserved timberland**. It includes unproductive forest land, which is incapable of producing annually 20 cubic feet per acre of industrial wood under natural conditions because of adverse site conditions such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness. It also includes urban forest land, which due to its location is unavailable for **sustained** timber harvesting (USDA Forest Service 1990b).

Ponderosa pine subregion. The area in the states of Oregon and Washington that is east of the crest of the Cascade Range (USDA Forest Service 1990b). More commonly, the "eastside" forests.

Rehabilitation. Management activity to allow establishment of desirable tree species (usually more valuable, faster growing, or more pest resistant species) in existing **stands** that have been severely damaged by insects and diseases, or have deteriorated due to a variety of factors (Gast et al. 1991).

Reserved timberland. Forest land that would otherwise be classified as **timberland** except that it is withdrawn from timber utilization by statute or administrative regulation (Waddell et al. 1989).

Restoration. See **rehabilitation.**

Risk. The probability of an undesirable event occurring within a specified period of time (Gast et al. 1991). In reference to fire prevention—the objective of which is to reduce the number of human-caused fires—it is those things or events that cause fires to start, including the actual igniting agents (matches, hot metal, etc.) and the people who may manufacture, use or handle those agents (Barney et al. 1984). In regard to insect populations, risk or risk-rating may contain components to evaluate the likelihood of an outbreak, the likelihood of trees being attacked (susceptibility), or the likelihood of trees being damaged (vulnerability) (Gast et al. 1991). See also **hazard**.

Salvage. The recovery of salvable dead trees, which are downed or standing and considered currently or potentially merchantable by regional standards (USDA Forest Service 1990b).

Sawtimber trees. Live trees of commercial species containing at least one 12-foot sawlog or two noncontiguous 8-foot logs, and meeting regional specifications for freedom from defect. **Softwood** trees must be at least 9.0 inches dbh, and hardwood trees must be at least 11.0 inches dbh (USDA Forest Service 1990b).

Seral. A biotic community that is in an early developmental, transitory stage in an ecological **succession** (Gast et al. 1991).

Seral species. A plant species characteristic of an early age in the development of a forest community; not permanent (Gast et al. 1991). See also **climax**.

Silviculture. The theory and practice of controlling the establishment, composition, constitution, and growth of forests (Gast et al. 1991, from SAF 1983).

Softwood. A coniferous tree, usually evergreen, having needles or scalelike leaves (USDA Forest Service 1990b).

Stability. Classic static stability means that two conditions are met for any entity: it has an equilibrium condition; and when disturbed, the entity returns to the original equilibrium (Botkin 1990).

Stand. A community, particularly of trees, possessing sufficient uniformity as regards composition, constitution, age, spatial arrangement, or condition, to be distinguishable from adjacent communities, so forming a **silvicultural** or management entity (SAF 1983).

Stand density. A quantitative measure of tree **stocking**; more precisely, a measure of the degree of crowding of trees (SAF 1983).

Stocking. The degree of occupancy of land by trees, measured by **basal area** and/or number of trees by size and spacing, compared to a stocking standard; i.e., the basal area and/or number of trees required to fully utilize the growth potential of the land (USDA Forest Service 1990b).

Succession (ecological). The process of development (or redevelopment) of an **ecosystem** over time (Botkin 1990).

Suitable forest land. Land to be managed for timber production on a regulated basis (Gast et al. 1991). Also termed suitable or suited timberland, these are national forest lands identified during the development and publication of a **National Forest Land and Resource Management Plan.**

"Suited" land. See **suitable forest land.**

Sustainability. 1. Resource sustainability requires a long-term balance between renewability and use that ensures the continuing productively of the resource (Frederick and Sedjo 1991). 2. In the context of **ecosystem management**, it has been defined as the balanced relationship between healthy ecological systems in a landscape and the needs of humans to maintain a quality lifestyle (USDA Forest Service 1993b).

Sustainable. Sustainable [resource] management implies using resource flows from existing stocks without seriously compromising the renewability of the resource for future use (Frederick and Sedjo 1991).

Sustainable ecosystem. Much talked about but hard to define. 1. Botkin (1990) implies that an **ecosystem is sustainable** by definition (see **ecosystem**). 2. Sustainable **ecosystems** are the integration of social expectations with land potentials, technology, and economic factors. The sustainability of ecological systems is defined by the historical range in **variability** of **ecosystem** patterns and processes at multiple hierarchial scales (Everett et al. 1993).

Sustained yield (management). The yield that a forest can produce continuously at a given intensity of management. NOTE: therefore implies continuous production so planned as to achieve at the earliest practical time a balance between increment (increase in tree volume or other measure in a given time period) and cutting (SAF 1983).

Thinning. A felling made in an immature **stand** in order to accelerate diamter increment but also, by suitable selection, to improve the average form [and condition] of the trees that remain (SAF 1983).

Timberland. **Forest land** that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland have the capability of producing in excess of 20 cubic feet per acre per year of industrial wood in natural **stands**. Currently inaccessible and inoperable areas are included.) (USDA Forest Service 1990b). See also **reserved timberland.**

"Unsuited" land. See **suitable forest land.**

Variability. The flux in composition, structure, and function of an **ecosystem** over the long term in a **landscape** is a definition of variability. In the historic context it describes natural disturbance and human interaction as a trend through time (USDA Forest Service 1993a).

Watershed. The drainage basin contributing water, organic matter, dissolved nutrients, and sediments to a stream or lake (USDA Forest Service 1993d).