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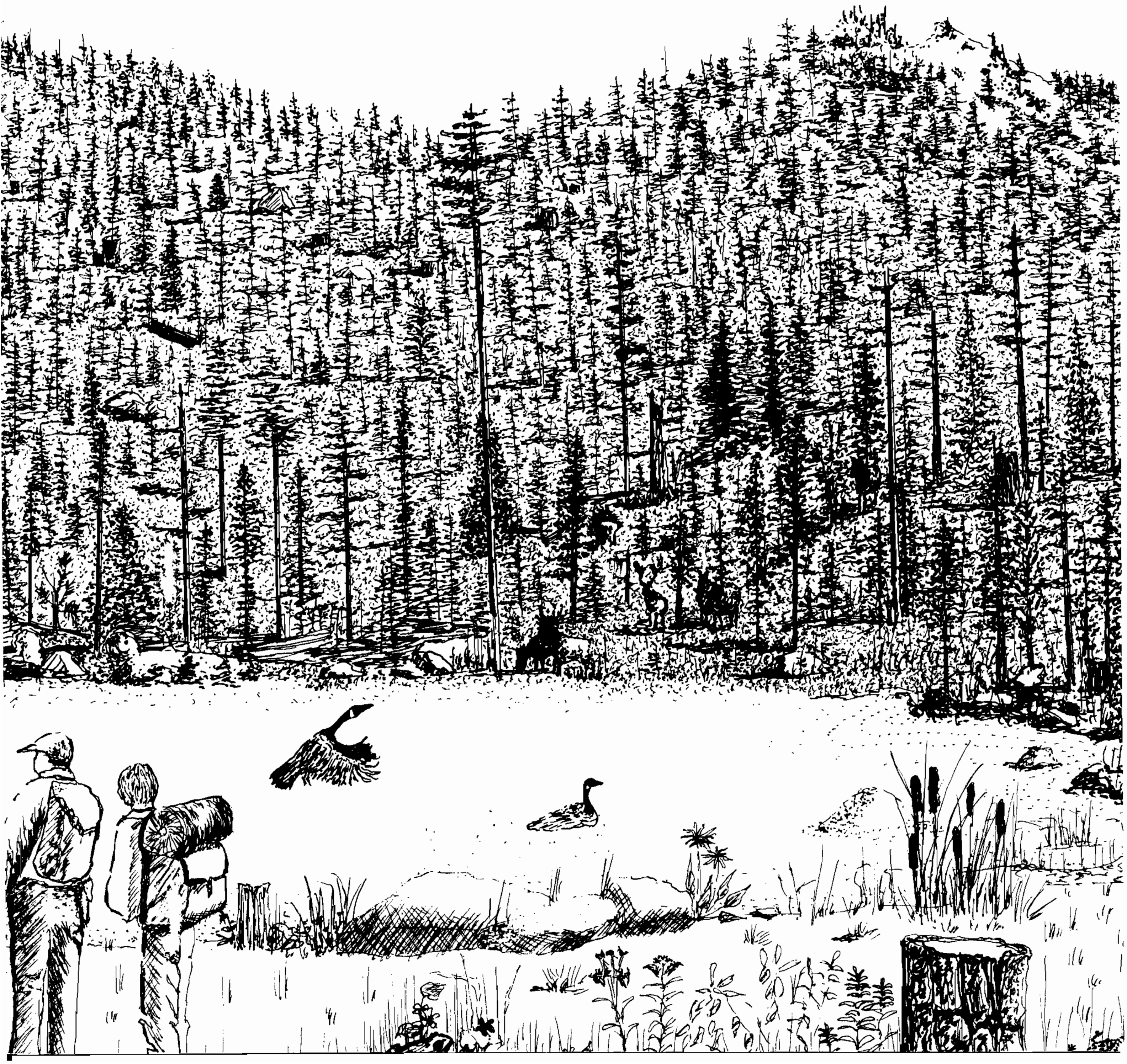
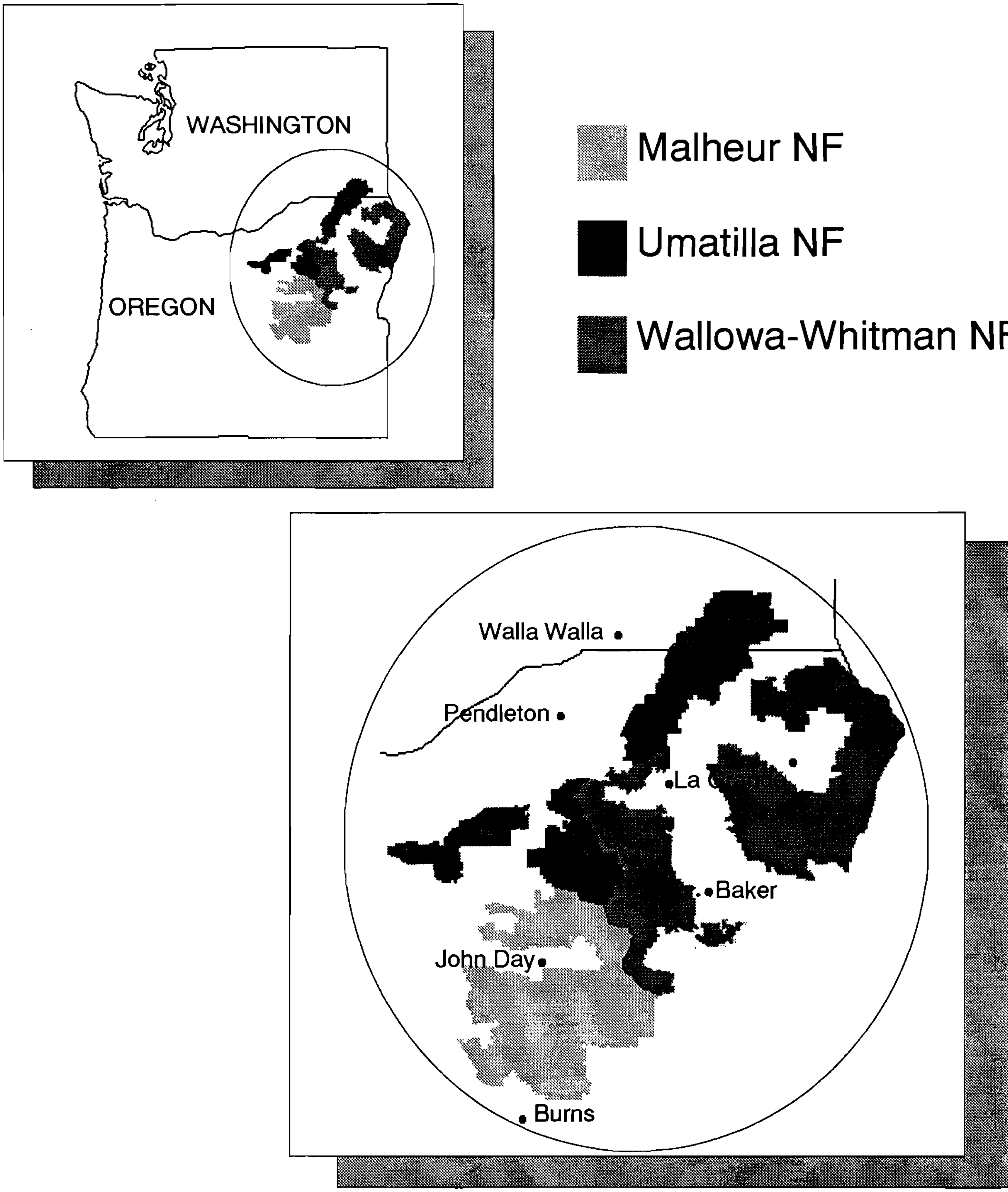
BLUE MOUNTAINS FOREST HEALTH REPORT

"New Perspectives in Forest Health"





Malheur, Umatilla and Wallowa-Whitman National Forests in the Blue Mountains of N.E. Oregon and S.E. Washington

BLUE MOUNTAINS FOREST HEALTH REPORT
"New Perspectives In Forest Health"

April 1991

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We regret that we are unable to personally acknowledge many other who have made contributions small and large, largely behind the scenes, to this effort. However, we hope they may be assured of our gratitude and recognition of their efforts in helping to bring this Project to completion.

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CHAPTER II

INTRODUCTION

Purpose

This report provides the Umatilla, Malheur, and Wallowa-Whitman National Forests (hereafter, the Blue Mountains National Forests) with a preliminary framework upon which land managers can build appropriate strategies for restoring and maintaining the health of forest resources in Northeast Oregon and Southeast Washington. In the pages that follow, some primary Issues of forest health are identified, analyses of existing conditions are provided, and a number of recommendations are made.

Although this report focuses on past, present, and future management of National Forest System lands, the authors have extended their analyses to include consideration of adjacent ownerships, and their recommendations encourage a cooperative approach to effective and responsible stewardship of all forest resources on all jurisdictions.

The Project Team recognizes that past forest management practices may have had more far-ranging effects than was previously thought. They offer perspectives on the various Issues that relate to specific resource concerns and provide recommendations for possible long-term solutions to the problem of declining forest health in the Blue Mountains.

Background

Epidemic insect infestations, several consecutive years of drought, and fires that seem to grow more catastrophic with each passing summer season have raised concerns for the health of the Blue Mountains National Forests to an unprecedented level. To neighbors and visitors alike, the effects are obvious and tragic. Dead and dying trees are hard to miss. To land managers of the Malheur, Umatilla, and Wallowa-Whitman National Forests the causes of this malaise are becoming more clear:

Decades of effective fire suppression and the selective harvest of late-seral tree species have altered the character of forest landscapes. Livestock has grazed on native grasses and other understory vegetation for many generations and further altered the landscape. However, it should be noted that past management incorporated the best available information at the time.

Resource managers believe it will require our best efforts to implement appropriate management projects that will help restore and sustain healthy forests. Scrupulous attention to the wildlife habitat-and-cover objectives that are defined in our Forest Plans will also be required, and we will continue to manage for old-growth habitat, Visual Quality Objectives, and riparian habitat. But even these projects do not guarantee success. Scientific evidence suggests that we have encouraged conditions that may result in catastrophic levels of tree mortality. Existing conditions jeopardize our ability to achieve the objectives we've outlined and the Desired Future Conditions we've described in our Plans.

There is a growing concern that existing conditions are stretching the ecological limits of the forest, and that the cumulative impacts of our actions have resulted in a less than fully productive environment. Much of the forest today is characterized by over-stocked, unevenaged stands; large populations of stagnated true fir occupy the sites where ponderosa pine once stood. Although these conditions exist over a large portion of the forests, much of the area is presently in a healthy and productive condition.

Today's Forest Plans reflect the future production of a wide array of resources and services that can, in fact, only be achieved within the limits provided by an ecologically viable forest. Land managers are now more than ever confronting factors that limit options for managing the many resources and values for which they are responsible. This phenomenon is to some extent the result of natural factors beyond human control; however, much of the existing situation is recognized to be the result of past human activities that have been less than sensitive to the needs of all resources.

Any attempts to address forest health must consider the delicate set of balances that constitute a forest ecosystem. Human and natural activities can interrupt a forest's ability to produce and support its resources. Cumulatively, changes of any scale may affect water quality, soil productivity, wildlife habitat, timber supplies, and recreation opportunities, as well as the many local resource-based economies that depend on the forest's bounty.

In response to the deteriorating health of the forests of Northeast Oregon, a number of concerned citizens have founded the Blue Mountains Natural Resource Institute (BMNRI). A cooperative venture of people from Federal, state, and local agencies, as well as private companies and other interest groups; BMNRI was formed to help improve and maintain forest health. Its goals are to enhance the long-term economic and social benefits derived from natural resources of the Blue Mountains and to do so in an environmentally sensitive way. The goals BMNRI has described are to be achieved through research, development, application, demonstration, and community education processes. The Blue Mountains National Forests are encouraged to work with this new partner. Included in this process is the fact that efforts must be made to address forest health problems in the context of the human environment. We must further define how management of the Blue Mountains National Forests (particularly with respect to Forest Health) affects the lifestyles and economies of the Blue Mountains communities.

Human Environment

The geographic area considered in this report includes forested lands in Northeast Oregon and in a small portion of Southeast Washington. The largest cities in this area are Walla Walla, Washington, and Lewiston, Idaho. Population centers in the general area include Boise, Idaho; the Tri-Cities area of Washington (Pasco, Richland, and Kennewick); Spokane, Washington, and Yakima, Washington.

The area as a whole is best described as a basic "rural" setting -- one whose economic existence has largely been based on the successful development of a natural-resource base. By providing high-quality hunting and fishing, boating, wilderness, and other recreational experiences, the area is recognized nationally for the contributions it makes to the overall well-being of the region.

Most national forest management activities are routine. Planning schedules and site-specific projects are the result of careful consideration of national forest resource capabilities and needs. Project implementation is based on coordinated interdisciplinary efforts that proceed according to established Standards and Guidelines described in our Forest Plans. Other activities, however, are not routine in the same sense; they require special consideration and different kinds of planning. For example, wildfire suppression projects are anticipated, but are hard to predict and manage.

Economic Implications: Forest managers and the public are concerned with how the Forests are managed. They want to know that available budgets are being spent reasonably, and that the resources are being managed wisely and well. An economic efficiency analysis would provide information on how the dollar-quantified costs and benefits compare to and include, long-term effects as well as short-term ones.

Probably the biggest concern voiced during the last round of Forest Planning was how Forest management would affect local jobs, personal income, and payments to local governments. There are few things more important to people than the stability of their livelihoods, how much they make, and how heavily they are taxed. A local effects analysis would address such concerns and must be considered as project decisions are made. See Appendix C.

Most area residents benefit in some measure from resources provided from these Forests, whether for their livelihood, or for the quality of the lifestyles they enjoy. Our dependence on forest resources is particularly apparent in: The timber industry's reliance on national forest products; the domestic uses of water that are supplied by Forest watersheds; the importance of forage that is provided for livestock; the special relationship that Native Americans have to their lands and waters; and the many recreation opportunities that are provided. The Blue Mountains National Forests' benefits to local economies are also manifested in more subtle ways. The Forests remit 25 percent of the gross receipts from product sales to local governments that depend on these monies for maintenance of area roads and schools. These governments also employ many area residents. Therefore, the economic effects of management activities must be considered before any project decisions are made (see Appendix C).

Social Implications: Area residents are well aware of the Forest Health problems. They have seen the parade of insects and diseases take their collective toll on the Forest resources. They have seen the devastating effects of large wildfires. They recognize that these problems have affected their use and enjoyment of the Blue Mountains forests.

Just how these Forest Health questions affect the public is a matter for sociological inquiry. What are the attitudes, the beliefs, the values society holds toward management of these resources? How can decisions be made without polarizing the communities and harming interpersonal relationships? How can some form of consensus be developed to address these concerns?

In years past the public largely accepted reactive management. If an insect outbreak occurred, it was sprayed. Today Forest Service managers are more inclined to address concerns from an ecosystem perspective. For example, integrating fire back into the ecosystem is, from a professional point of view, ecologically sound, but the concept may meet with some resistance. Therefore, questions remain as to how this can be achieved in the larger sociological context.

Forest management affects area inhabitants who depend on fuelwood from public lands to heat their homes. It affects the kind of views they see, and how easily they can travel to their hunting camps. All of the Blue Mountains National Forests work to restore fish habitat and to address the concerns for wildlife species that are so important to Native Americans and others. Native American cultures use the Blue Mountains National Forests in special ways that must be respected and considered in our management activities.

While the Blue Mountains National Forests and the surrounding communities are distant from major metropolitan areas, our connections to larger populations and wider areas of concern are becoming more obvious and more keenly felt. The media have reinforced the links to our larger customer-community, our neighbors are able to participate in national forest planning as members of larger groups, and the Interstate Highways and other transportation systems connect us to the National neighborhood. As a result the mainstays of our local economies (farming, ranching, timber, minerals, and tourism) have become more important to the nation at large.

Given the importance of the National Forests in the everyday lives of the local inhabitants, it is understandable that they would develop a special sense of responsibility for them. Many people have come to feel a real sense of ownership of the Forests and the resources they provide. As Forest managers, we are routinely challenged to respect these feelings, yet we must remain committed to the broader responsibility of managing the Blue MountainsNational Forests for all Americans.

Please refer to the Forest Plan EIS's for the Umatilla, Malheur, and Wallowa-Whitman National Forests for thorough discussions of the social and economic environments affected by National Forest management.

National Direction

The 1990 Forest and Rangeland Renewable Resources Planning Act (RPA) predicts that demands for most renewable natural resources will increase in the future. This prognosis readily applies to the demand for resources of the Blue Mountains National Forests. As managers of our public lands we have an opportunity to respond positively to these increases through a course of action that takes best advantage of the biological potential and productivity of a finite land base.

The USDA Forest Service is committed to change. Mandates of the various laws under which we work instruct us to conduct our activities in response to "...the long-term rhythms of nature and to the shifting needs and desires of people." This instruction is made especially clear in the future priorities that are set by RPA for management of Forest Service programs:

> "The direction of Forest Service programs is changing. While renewing the commitment to multiple-use management, the balance of multiple-use resources will be better rounded out and will be implemented with greater environmental sensitivity. Examples of change are these four high-priority themes:
>
> - Enhancing recreation, wildlife, and fisheries resources,
> - ensuring that commodity production is environmentally acceptable,
> - improving scientific knowledge about natural resources, and
> - responding to global resource issues"

RPA expands on these themes with some language that leaves no doubt as to the direction that individual Forest's land management planning will go: "Each of these themes will emphasize the long-term health, diversity, and productivity of the land."

The concern for healthy and productive forests is not a new theme. 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 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 the *National Forest Management Act of 1976* (NFMA). This legislation 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..."

In response to the frequent need to protect the forest from fire, insects, and diseases, NFMA allows national forests to exceed harvest-size limits that are set for "areas to be cut in one harvest operation." Such limitations as are described in Regional Planning Guidelines and in Forest Plans are, therefore, 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."

NFMA further allows that standards requiring that stands of trees generally must have reached their culmination of mean annual increment 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 for 10 years, "... except for salvage sales or sales necessitated to protect other multiple-use values...".

Finally, the USDA Forest Service identified eight issues that relate to forest management activities affecting forest health. Options were developed as recommendations for resolving the issues. These were published in 1988 as "Forest Health Through Silviculture and Integrated Pest Management--A Strategic Plan." The Plan was to enhance and maintain healthy forest conditions. Furthermore, additional analyses and further development of alternatives has ensued, and the Forest Health Steering Committee has implemented an Action Plan to address in practical terms, and fully implement, the National recommendations. The Blue Mountains Forest Health Project has used the National effort as a framework for analysis and recommendations contained in this Report.

Forest Plans

The Blue Mountains Forest Plans provide the basis for taking a proactive approach to restoring and maintaining a healthy, diverse, and productive forest environment. Silvicultural activities that are sensitive to all forest resources are the principal tools for maintaining healthy vegetation over the long term.

The Blue Mountains National Forests comprise about 5,319,000 acres of National Forest land. Of that total, about 2,275,000 acres are identified in the Forest Plans as being suitable for timber production. Suitable timber lands offer the greatest opportunity for using integrated resource management techniques to promote tree vigor, ecological diversity and long-term productivity. Vegetative manipulation is the most effective means of achieving much of the Desired Future Condition specified in the Forest Plans.

Tables 1, 2, and 3 list the Management Allocations that are described in each of the three Forest Plans. The total acres of each Allocation and the total acres of lands suitable for timber production in each Allocation are shown for each Forest. Appendix A contains excerpts of management standards and guidelines that are provided in Forest Plans and Records of Decisions. These standards and guidelines relate primarily to integrated pest management techniques and direction that allows for response to catastrophic events. Appendix A does not include all the Forest Plan direction that influences health conditions of the Blue Mountains National Forests. Reviewers should consult appropriate documents for additional, specific information.

Table 1

MANAGEMENT AREAS BY ACRE FOR THE MALHEUR NATIONAL FOREST			
Management Areas		Total Acres	Suitable Acres
1	General Forest	553,053	526,811
2	Rangeland	99,203	0
3A	Non-Anadromous Riparian	19,268	10,169
3B	Anadromous Riparian	28,092	9,891
4A	Big-Game Winter Range Maintenance	177,406	115,164
5	Bald Eagle Winter Roosts	4,040	0
6A	Strawberry Mountain Wilderness	68,700	0
6B	Monument Rock Wilderness	12,620	0
7	Scenic Area	13,322	0
8	Special Interest Areas	246	0
9	Research Natural Areas	750	0
10	Semi-Primitive Non-Motorized Recreation Areas	48,888	0
11	Semi-Primitive Motorized Recreation Areas	14,578	0
12	Developed Recreation Sites	484	0
13	Old Growth	72,690	22,800
14	Visual Corridors	186,682	131,667
16	Minimum Level Management	74,668	0
17	Byram Gulch Municipal Supply Watershed	300	0
18	Long Creek Municipal Supply Watershed	224	224
19	Administrative Sites	1,369	0
20A	Wildlife Emphasis/Scheduled Harvest Dry Cabin	14,629	7,402
20B	Wildlife Emphasis/Scheduled Harvest Utley	9,045	4,652
21	Wildlife Emphasis With Non-Scheduled Harvest	22,076	0
22	Wild and Scenic River	10,256	7,190
	Roads and Water	26,833	0
	Totals	1,459,422	835,970

Table 2

MANAGEMENT AREAS BY ACRES FOR THE UMATILLA NATIONAL FOREST			
Management Areas		Total Acres	Suitable Acres
A1	Nonmotorized Dispersed Recreation	27,319	0
A2	OHV Recreation	7,523	0
A3	Viewshed 1	43,714	19,772
A4	Viewshed 2	28,680	15,077
A5	Roaded Natural	4,736	2,903
A6	Developed Recreation	4,432	0
A7	Wild and Scenic River	7,605	3,334
A8	Scenic Areas	31,442	0
A9	Special Interest Area	3,152	0
A10	Wenaha-Tucannon Special Area	3,294	2,547
B1	Wilderness	304,400	0
C1	Dedicated Old Growth	41,184	0
C2	Managed Old Growth	3,622	3,455
C3	Big Game Winter Range	152,756	50,037
C3A	Sensitive Big Game Winter Range	8,161	0
C4	Wildlife Habitat Emphasis	258,878	202,431
C5	Riparian/Wildlife	27,208	17,158
C7	Special Fish Management Area	105,337	87,477
C8	Grass-Tree Mosaic	98,471	0
D2	Research Natural Area	1,586	0
E1	Timber/Forage	91,421	55,406
E2	Timber and Big Game	199,549	154,970
F2	Mill Creek Municipal Watershed	20,815	0
F3	High Ridge Evaluation Area	880	880
F4	Walla Walla River Watershed	34,950	3,382
	Totals	1,511,115	618,769

Table 3

MANAGEMENT AREAS BY ACRES FOR THE WALLOWA-WHITMAN NATIONAL FOREST			
Management Areas		Total Acres	Suitable Acres
1	Timber Emphasis	716,245	510,432
3A	Big Game Habitat Emphasis	382,113	226,530
4	Wilderness	582,700	0
5	Phillips Lake Area	4,967	1,743
6	Roadless Recreation (Backcountry)	122,788	0
7	Wild and Scenic River	26,909	4,021
8	HCNRA Snake River Corridor	14,355	0
9	HCNRA Disp. Rec./Nat. Veg.	161,078	0
10	HCNRA Forage	123,029	0
11	HCNRA Disp. Rec/Tmbr. Mgt.	70,706	42,323
12	Research Natural Areas	15,160	0
13	Homestead Further Planning Area	5,733	0
14	Starkey Exp. For. and Range	27,051	0
15	Old-Growth Forest	36,750	0
16	Administrative and Recreation Sites	5,744	0
17	Utility Corridors	6,594	0
18	Anadromous Fish Emphasis	59,743	35,416
	Totals	2,349,215	820,465

Methodology

The Forest Health Project team identified 12 Issues that are germane to the problem of deteriorating forest health in the Blue Mountains. Eight of the Issues were identified in the Forest Service report, *Forest Health Through Silviculture and Integrated Pest Management - A Strategic Plan*. The other four were identified when the Project Team sought to broaden the scope of their analyses to reflect concerns for forest health that may not relate to integrated pest management. Each of the Issues are addressed in the context of Forest Pests, Biological Diversity, Long-Term Productivity, the Role of Fire, and Watershed Health.

Assessments of resource conditions in the Blue Mountains National Forests were conducted to consider each of these subject areas. The assessments discuss present conditions and offer responses to the issues and recommendations for future maintenance and enhancement of forest health. The recommendations included in this document will require clarification as Forest planning proceeds, responsibilities are assigned, and as implementation plans and timeframes are developed by the individual Forests.

Data used by the Project Team were gathered from historic pest- and fire-management records, recent aerial surveys of insect damage, Biological Evaluations, Forest Plans, in-depth literature searches, informal contacts with other agencies and interested persons, and from the personal knowledge and experience of individual team members.

The comprehensive information the districts provided proved invaluable to the Team's analysis of forest health, and the changing resources and landscapes of the Blue Mountains. The information provided also identified how insects and diseases have impacted resources on National Forest lands. This information has examples and actual District-level data and information to which we have frequently referred in many sections of this Report.

Resource effects described in this document are discussed in broad terms. Individual projects that may be proposed in response to the Team's recommendations will be subject to site-specific analyses and compliance with National Environmental Policy Act (NEPA) policies and procedures.

Strategies and Recommendations

What follows are the principal strategies and recommendations formulated by the Forest Health Team to address the health problems currently facing the Blue Mountains National Forests. (For complete discussion, see Appendix G.) Right now, the three Forests have the potential to undergo massively damaging infestations, infections, and conflagration sized wildfires. If we are to avert this tragedy, action must be undertaken immediately. But what to do? The problems that the forest pests present are numerous, varied, and widely interconnected. If one action is taken, its results will be evident among other resources. Legal barriers and deficiencies of information further combine to hobble resource managers' abilities to act in a wise and timely manner. We understand these difficulties and offer the following recommendations as a broad platform on which to base future management actions. It is our fervent hope that with cooperation and understanding between all involved parties we can use these recommendations in the wisest possible manner to bring about the benefits of healthy forests.

The Strategy statements are as follows. More thorough discussion can be found on the next few pages. The implementation of these strategies, in some cases, will require further analysis, consideration of alternative procedures, scheduling, and assignment of responsibilities to assure their success.

1. Foster public awareness and participation in addressing long-term forest health issues as they relate to both the human and natural environments.

2. Review Forest Plans to insure desired future conditions are appropriate given the present condition and trend of forest health in the Blue Mountains.

3. Utilize fire and silvicultural means to restore and maintain forest health in the Blue Mountains within the framework of the desired future conditions described in the Forest Plans.

4. Improve coordination of Forest Service land management activities between adjacent landowners and other government agencies to insure that forest health concerns are addressed.

5. Promote integrated resource analysis to insure adequate consideration of forest health needs in terms of biological diversity, long-term productivity, watershed values, insect and disease management, and cumulative effects on a landscape scale.

6. Encourage research for the purposes of meeting information needs and identifying standards and procedures for monitoring forest health in the Blue Mountains.

7. Develop technology and information resources in conjunction with integrated resource management in order to better address long-term restoration and maintenance of forest health.

Strategy 1

FOSTER PUBLIC AWARENESS AND PARTICIPATION IN ADDRESSING LONG-TERM FOREST HEALTH ISSUES AS THEY RELATE TO BOTH THE HUMAN AND NATURAL ENVIRONMENTS.

The Forests should involve the public through forums, shared information, use of demonstration areas, and the NEPA process.

Showcase Integrated Pest Management strategies in selected recreation sites and visitor centers with interpretive displays. Foster understanding of forest health and ecosystem interaction among Forest Service managers.

Develop public information and involvement programs that foster public awareness of, and participation in, long-term forest health.

Revitalize the public information program with messages that share the Forest Service vision of the healthy forest, and demonstrate that fire and smoke have intricate and important roles in the function of these forests.

Revise the fire prevention program by stressing that the wise use of prescribed fire (planned and unplanned ignitions) can be an effective tool for creating and maintaining healthy forests.

Education is the key to changing the Forest Service's image of "protectionism" to one of "utilization" regarding the role of fire in maintaining healthy forests.

Foster local community (and other) resource management agencies' support for use of fire as a necessary tool to achieve forest health.

A mixture of ownerships with different management practices intermingles with National Forest lands in the Blue Mountains. The use of fire to promote vegetative diversity and increase forest health entails certain effects which may be feared or not accepted by adjacent landowners. Proactive, coordinated efforts at all levels of Federal, State, and Local governments and publics is essential to fostering the use of prescribed fire as a means to restore and maintain forest health.

Project and Forest planning should foster local public involvement and cooperation in the formulation of historic and desired conditions for the promotions of forest health.

We need to convey to the public that we are concerned about managing forest ecosystems that are largely defined within the context of biodiversity. We should not make decisions soley on the basis of short-term outputs and services.

Use the Blue Mountains Natural Resources Institute (BMNRI) as a coordinator for public information sharing concerning the Forest Health issue.

The BMNRI should facilitate a forum where public views can be expressed, considered, and provided the opportunity to influence decisions. Meetings, presentations, displays, newspaper articles, the Forest Health video, and other public means can be used for information sharing on Forest Health problems and solutions.

Biodiversity enhancing practices should be demonstrated on selected areas of the Blue Mountains National Forests, and the public should be invited to examine the results.

Forests and the BMNRI should collaborate to conduct public tours, disseminate brochures, and invite the news media to visit these areas.

Strategy 2

REVIEW FOREST PLANS TO INSURE DESIRED FUTURE CONDITIONS ARE APPROPRIATE GIVEN THE PRESENT CONDITION AND TREND OF FOREST HEALTH IN THE BLUE MOUNTAINS.

The three Forests need to define more completely the values, quantities, and expectations for both the commodity and non-commodity resource outputs needed to maintain long-term productivity of their forest ecosystems.

Develop insect and disease management strategies consistent with resource goals contained within the Forest Plans.

Develop a process, consistent with the Forest Plans, which provides for more timely responses to catastrophic events impacting long-term forest health.

It is recommended that Forest Pest Management (R-6) take the lead in identifying forest pest outbreaks and other natural catastrophic events for which a programmatic document would be appropriate.

Require that the effects of genetic, species, and landscape diversity be addressed in project planning activities and Forest Plan updates.

Understanding the relationship between the affects of multiple projects over long periods of time and across entire landscapes will allow for better estimates of the total ecological effects of management activities.

Integrated pest management and other resource management practices that affect short-term resources, yet best achieve desired future condition and long-term resource goals, should be carefully considered by the Forests.

Strategy 3

UTILIZE FIRE AND SILVICULTURAL MEANS TO RESTORE AND MAINTAIN FOREST HEALTH IN THE BLUE MOUNTAINS WITHIN THE FRAMEWORK OF THE DESIRED FUTURE CONDITIONS DESCRIBED IN THE FOREST PLANS.

3a-Reintroduce fire as a means to restore and maintain forest health through modifying, diversifying, and rejuvenating forest landscapes.

An analysis of the existing vegetation patterns and specific known fire tolerances of certain plant species indicates that the historic role of fire in the Blue Mountains varied from low intensity surface burns to total stand replacement burns. A similar array of fires is necessary to achieve the vegetational mosaic historically common to the Blue Mountains. However, due to the long period of fire exclusion, a gradual reintroduction of fire to these ecosystems is expected to prevail.

Encourage re-introduction of surface fires back into the ecosystem to protect and maintain stands.

Catastrophic stand replacement fires and catastrophic pest damage can be avoided by converting stands back to seral species on sites that were historically maintained in seral condition by wildfire. This action would enhance wildlife habitat in the short- and long-term.

Develop fire management plans establishing criteria, goals, and objectives for utilizing unplanned and planned ignitions as means to restore and maintain forest health.

In areas where timber and other resource objectives will not be jeopardized, unplanned ignitions could be designated as prescribed fires if predetermined criteria outlined in an approved fire management plan were met.

Restore and maintain seral species (as appropriate) on sites that were historically maintained by wildfire.

Recommend that appropriate jurisdictional agencies or legislative bodies explore effective means of continued fire use while mitigating significant impacts to the air resource.

The 1990 RPA Program recognizes that catastrophic fire "will continue to be a concern until build-up of natural fuel is eliminated or prevented." Land managers also recognize that a major contributor to the existing fuels situation has been fire exclusion. This has resulted both directly, as accumulation of dead and down surface fuels, and indirectly, as insect or pathogen activity increases in late-seral vegetation communities (successional advancement). Achievement of the RPA goal to prevent catastrophic fires in the fire-prone forests of the Blue Mountains will require an increased, on-going use of fire as an effective and practical management tool. Use of state-of-the-art prescribed burning techniques could still result in periodic short-term impacts to air quality. Appropriate agencies and legislative bodies need to be open to on-going evaluation of existing air resource provisions and consider needs for supplemental revisions.

3b-Utilize silvicultural means to restore and maintain forest health through modifying, diversifying and rejuvenating forest landscapes.

Enhance forest health and maintain big game cover through the use of silvicultural systems which create multi-species forest stands with stocking levels low enough to make them less susceptible to pests.

Within land allocations that emphasize timber management, appropriate salvage operations should be conducted as soon after a fire event as possible.

The time lag between tree mortality by fire and retention of sufficient useable wood fiber for a feasible harvesting operation is critical. For some species, this timeframe covers only one year. Once a management decision is made to salvage harvest, processes and procedures should proceed quickly. A review of present methods and the determination of the possible means to 'streamline' NEPA and timber sale planning are necessary to accomplish this recommendation.

Stands with epidemic pests should be given treatment priority based on current losses, potential for future losses, and productivity potential.

Within resource objectives, emphasize the thinning of ponderosa pine stands where high risks of insect- or fire-caused mortality exist.

Strategy 4

IMPROVE COORDINATION OF FOREST SERVICE LAND MANAGEMENT ACTIVITIES BETWEEN ADJACENT LANDOWNERS AND OTHER GOVERNMENT AGENCIES TO INSURE THAT FOREST HEALTH CONCERNS ARE ADDRESSED.

Conduct studies between the Blue Mountains Forests and their cooperators as part of the Forest Service Economic Diversification Studies Program.

The purpose of these studies is to identify economic opportunities which result from the use of small-diameter wood products on the National Forests of northeastern Oregon.

Develop and promote cooperation among adjacent landowners.

Public and private lands need to be managed in a mutually beneficial manner, especially with regard to Forest Health concerns that can cross ownership boundaries.

The Blue Mountains Natural Resources Institute, with support from the Forests, should serve as the primary catalyst in building coalitions which will help to better define long-term productivity, biological diversity, and changing social values.

The applied practices and results of biological diversity enhancement activities should be demonstrated on selected areas within the Blue Mountains National Forests.

The Forests and the BMNRI should collaborate to conduct public tours, disseminate brochures, and invite the news media to visit these areas.

Foster awareness among jurisdictional agencies (i.e. Oregon Department of Environmental Quality) and legislative bodies regarding the beneficial role fire could play in restoring and maintaining forest health.

The effects of implementing the Tri-Regional Anadromous Fish Policy on diversity, long-term productivity, and desired future condition should be addressed at all levels of planning and implementation.

Anadromous fisheries are an important feature of forest diversity. Restoration and maintenance of these fisheries is a desirable activity. Live, healthy trees maintained over time are essential for the soil integrity and shade required for adequate fish habitat.

Strategy 5

PROMOTE INTEGRATED RESOURCE ANALYSIS TO INSURE ADEQUATE CONSIDERATION OF FOREST HEALTH NEEDS IN TERMS OF BIOLOGICAL DIVERSITY, LONG-TERM PRODUCTIVITY, WATERSHED VALUES, INSECT AND DISEASE MANAGEMENT, AND CUMULATIVE EFFECTS ON A LANDSCAPE SCALE.

Direct Districts of the Blue Mountains National Forests to develop individual Forest Health Implementation Plans.

The Pine Ranger District (WAW) accomplished this is in 1990. Such plans identify District-level goals and objectives and appropriate tasks for improving ecosystem health and achieve Desired Future Conditions. The development of these plans should be done by Districts with assistance from the BMPMZ (See Appendix B).

Provide for the long-term maintenance of "old-growth" forest allocations and recognize the role such allocations and their dependent species play in maintaining forest health.

Within each designated planning area, set aside "old-growth" core, transition, and corridor habitats.

Develop operational criteria for achieving biological diversity and healthy forests.

Identify which elements of the ecosystem are being considered in any given project. Specify measurements or characteristics that evaluate or distinguish these elements. Describe how the differences between elements are meaningful for management decisions.

Arrange stand size and successional stages to provide forage, cover, edge habitat, and other special needs within each plant community in order to meet biological diversity and forest health objectives over time.

Emphasize the growth and supply of merchantable trees in the sizes, age-classes, quality, quantity and species mixes that most clearly address market demands within the framework of forest health goals.

Project planning should address the question of appropriate levels of retention and recruitment of snags and down woody material.

Restoration and maintenance of forest health must be addressed within the context of the Tri-Regional Anadromous Fish Policy.

Strategy 6

ENCOURAGE RESEARCH FOR THE PURPOSES OF MEETING INFORMATION NEEDS AND IDENTIFYING STANDARDS AND PROCEDURES FOR MONITORING FOREST HEALTH IN THE BLUE MOUNTAINS.

Focus research on the following:
- **long-term forest productivity;**
- **priority forest pests, resource interactions, and management needs;**
- **biological diversity;**

- **social and economic values; and**
- **anadromous fish habitat.**

Define and develop the standards, criteria, procedures, and tools for monitoring forest health.

Forest Pest Management (WO, R-6) and Forest Health RD&A should place high priority on developing these aids and improving appropriate technology transfer tools.

Initiate research that will more clearly define the acceptable range of cumulative effects of equipment-caused soil disturbance on costs, benefits, growth, yield and long-term productivity.

Since soil organic matter levels and compaction appear to be the main variables in linking management activities to long-term site productivity, it is essential that the soil and all its properties be protected (for helpful guidelines given by interdisciplinary determinations of desired residues, see R-6 fuel management notes, 1979).

Through the BMNRI, conduct problem analyses of forest health issues.

Strategy 7

DEVELOP TECHNOLOGY AND INFORMATION RESOURCES IN CONJUNCTION WITH INTEGRATED RESOURCE MANAGEMENT IN ORDER TO BETTER ADDRESS LONG-TERM RESTORATION AND MAINTENANCE OF FOREST HEALTH.

Develop models for the following:
- **-- mountain pine beetle impact on ponderosa pine;**
- **-- Douglas-fir beetle-caused losses and population trends;**
- **-- true fir losses from stem decays;**
- **-- fir engraver-caused losses;**
- **-- spruce beetle-caused losses; and**
- **-- cumulative effects across forest landscapes.**

Promote methods for adding Integrated Pest Management input to resource management prescriptions.

Pest specialists should be consulted during the environmental analysis process, or be members of ID teams on projects where pest concerns and issues are considered important.

Provide training to District level personnel in biological diversity principles, philosophy, and adaptive management activities as they relate to healthy forests.

Workshops similar to the Regional Biodiversity Workshop recently held at Spokane should be available to Ranger Districts. Zone Ecologists and Zone Forest Pest Managers would be responsible for conducting the workshops.

Support forest health objectives and economic diversity consistent with the Pacific Northwest Strategy by providing greater opportunities to remove wood fiber which is in excess of the amount required to supply noncommodity resources. Techniques and sound economic methods should be developed that encourage such removal. Examples are chipping in the woods, small diameter thinnings, cull removal, light cable systems, etc.

Establish a demonstration area "Learning Center" in the Blue Mountains that studies and applies new technologies to enhancing our knowledge of forest health.

Identify potential pest losses and outbreaks through risk rating and monitoring, and use that data when scheduling management activities. Apply systems to risk-rate stands, analysis areas, timber types, and plant communities for susceptibility to pests.

CHAPTER I

FOREST HEALTH ISSUES

FOREST HEALTH ISSUES

Issue 1 - **Planning**

A steady decline in the overall health of natural resources in the Blue Mountains has created a concern that management of forest pests, maintenance or enhancement of biological diversity and watershed health, and long-term site productivity may not be adequately addressed in these Blue Mountains National Forest Plans.

Rationale

- Achieving Desired Future Conditions through project planning is inhibited by the poor health of the forests.

- Public values, needs, and expectations have historically been expressed in terms of commodity and non-commodity output. Increased public awareness of ecological issues and a growing recognition of the need for ecosystem management suggest a need to redefine Forest goals and objectives.

- There is disagreement concerning the adequacy of modeling tools used to assess current and future losses to forest pests and the impact of management activities on watersheds.

- When Forest Plans were approved, GIS technology and other computer-assisted tools were not available to the decision makers.

- Forest Plans provide direction for response to those catastrophic events which influence forest health that may conflict with short-term (and sometimes long-term) objectives for some resources.

Issue 2 - **Public Involvement**

Comprehensive planning concepts such as integrated pest management have been developed to address the forest health issue. Public involvement and community outreach will be necessary to perform integrated resource management planning on the national forests.

Rationale

- Present-day public expectations are likely to conflict with plans to manage resources for long-term forest health.

- Increased awareness of and concern for the environment have focused public attention on forest management.

- Public response to Draft Forest Plans and recent public involvement activities indicate that there is a general misunderstanding of multiple-use concepts and integrated resource planning.

Issue 3 - **Resource Management**

Certain resource management practices have contributed to the decline of forest health on the Blue Mountains National Forests. Adequate means of improving forest health may conflict with other program objectives. An ecological approach to resource management is needed.

Rationale

- Generally, ecosystem management has not been considered in project planning and implementation. The scope and scale of our analyses have often been too narrow.

- The importance of riparian zones is disproportionate to the amount of actual land they comprise.

- It is likely that Tri-Regional Anadromous Fish Management policy will result in modifications of Forest Plans and associated resource goals and objectives.

- Some management activities that would promote forest health conflict with goals and objectives for managing forest resources other than timber; e.g., where timber management activities would help make a forest less susceptible to insects, disease, and fire, and increase site productivity, some elk thermal cover and anadromous fish habitat might be adversely affected for the short-term.

- Some management activities that would protect or promote forest health would conflict with goals and objectives for maintaining timber production; e.g., where damaged or dead timber is retained to provide wildlife habitat or protect water quality, salvageable wood fiber volume is lost.

- Public responses to Draft Forest Plans and recent public involvement activities indicate that there is a general misunderstanding of how forest health relates to all forest resources.

- Aggressive fire suppression and timber-harvest practices that increase trees' susceptibility to pest and fire problems have contributed to the deterioration of forest health.

- Laws and regulations often prohibit timely salvage of dead or damaged timber. Procedural delays result in substantial loss of wood fiber volume and value.

- Existing utilization standards and the lack of markets for small timber result in high administrative costs. Land managers recognize that revised utilization standards and improved markets would provide public incentives for cooperative activities that would contribute to improved forest health.

- A significant amount of suitable timber land is being ravaged by insects and disease. The Forests' ability to meet timber-harvest program levels described in their Forest Plans has been reduced.

- Tree vigor has declined in many areas of the Blue Mountains Forests.

Issue 4 - **Pest Prevention and Suppression**

Historically, procedural and funding "barriers" have sometimes prohibited prompt and effective response to pest outbreaks.

Rationale

- The scheduling and funding of pest management activities have not been conducive to long-term planning and programming.
- No mechanism yet exists for projecting forest pest suppression funding needs beyond one year.
- It is often the case that stands in need of pest suppression activity go untreated because they are perceived to have limited economic value, or they simply miss out in the heavy competition for limited funds.

Issue 5 - **Environmental Analysis**

Programmatic Environmental Impact Statements that could be used to simplify project-level NEPA analyses and shorten response time to pest outbreaks are not available for all major catastrophic events that occur in the Blue Mountains National Forests. Flexibility to categorically exclude is limited.

Rationale

- NEPA requirements and organizational limitations inhibit our ability to quickly respond to catastrophic events that influence forest health.
- Programmatic NEPA documents would allow us to "tier" our project-level analyses to them, which could result in quicker response time. Forest Plan Environmental Impact Statements do not address the effects of responding to recurring catastrophic events (fire, insect infestations, blowdowns, floods).

Issue 6 - **Pesticides**

Long-term solutions to epidemic infestations of pests will be needed to assist in maintaining forest health. While a full range of management tools will be considered for use, the Forests' reliance on chemical and biological pesticides as corrective actions should diminish as forest health improves.

Rationale

- Pesticide use has been and will continue to be controversial.
- Reliance on the exclusive use of pesticides is prohibited in the Pacific Northwest Region.
- Pesticides and herbicides do not provide long-term solutions to infestation by insects, diseases, or unwanted vegetation.

Issue 7 - **Pest-suppression Technology**

Forest resources can often be effectively and efficiently managed by existing technologies and silvicultural treatment methods that have not been used to their fullest extent. These technologies should be used and new technologies should be developed and used, as appropriate.

Rationale

- New methods of manipulating insect populations have not been fully developed or pilot-tested in the Blue Mountains; e.g., bait-and-cut strategies and semiochemicals have been successful in other areas, but have not been tried in the Blue Mountains National Forests.

- Available techniques for controlling forest diseases are not fully understood.

- The effectiveness of technologies now in use has not been monitored to a great extent; e.g., the effectiveness of budworm suppression usually is not closely monitored beyond the year of treatment.

- Silvicultural treatments and the use of prescribed fire offer long-term and more economical solutions than short-term treatments.

Issue 8 - **Forest Health Monitoring**

Definitions of forest health vary across the full range of land allocations and among land stewards of the various "specialty" disciplines. Agency standards of forest health that are specific to individual allocations would help to establish monitoring strategies and procedures that could be used to help achieve the Desired Future Conditions described in Forest Plans.

Rationale

- Monitoring plans that are described in Forest Plans could be expanded to include allowance for the funding and personnel necessary to adequately monitor forest health improvement projects.

- Field personnel have reported that adequate standards and procedures for monitoring and reporting on forest health indicators are not in place.

Issue 9 - **Coordination**

Resource managers have identified a need for coordinating all forest pest prevention, suppression, and monitoring activities with adjacent landowners to promote healthy forest landscapes.

Rationale

- Comprehensive treatment of affected forest land will sometimes be necessary to effectively handle wide-spread disease and insect infestations.

- Because resource objectives vary among neighboring landowners, continuous communications will be necessary to collectively work toward regaining forest health.

- The special needs and rights of Native Americans must be considered in national forest management as we work with Tribes on a government-to-government basis.

Issue 10 - **The Role of Fire**

With increased emphasis on fire suppression, the desirable influences of fire have diminished. In order to restore and maintain healthy forests, a better understanding of the role of fire on forest landscapes is needed, and a greater use of fire for vegetation and fuels management may be indicated.

Rationale

- 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.

- 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.

- In accordance with the "Mediated Agreement" that followed publication of the Competing and Unwanted Vegetation Management Final EIS, any management activity that would affect vegetation on national forest lands will be considered through a process of site-specific analysis.

Issue 11 - **Biodiversity**

Past management practices have not necessarily considered the maintenance or enhancement of ecological diversity. Increased awareness and understanding of ecosystems could help avoid further jeopardy to forest ecosystems.

Rationale

- There is increasing concern within, and outside of, the Forest Service with maintaining diversity.

- In some situations intensive management of forest resources has reduced the diversity that is inherent in natural successional processes. Opportunities to maintain or enhance diversity may be found in management practices that mimic nature.

- Increasingly, scientific evidence suggests that more consideration should be given to the role that stable plant and animal communities play in maintaining ecosystem diversity.

- Available tools and knowledge have often been inadequate to identify or assess "appropriate" diversity levels.

- As the scientific community gains a better understanding of the importance of ecosystem diversity in natural resource management, the information they gather should be shared with land managers and the public.

Issue 12 - **Long-term Site Productivity**

Some commonly endorsed or recommended management practices are contributing to the reduction of long-term productivity. Recognition of this fact suggests that current practices could be modified in ways that will better serve to ensure maintenance of site productivity.

Rationale

- Data suggest that productivity has diminished where soils have been compacted or displaced by management activities; where reserves of dead-and-down material have been removed; and where lands have been over-grazed. Examples such as these can serve to help land managers to better understand necessary elements of forest health.
- Historically, intense wildfires have severely damaged soils, increased their susceptibility to displacement, and reduced overall site productivity.
- The concept of "New Perspectives in Forestry" may offer an opportunity for land managers to look at creative new approaches to managing ecosystems rather than individual resources, and may be a means by which long-term site productivity can be enhanced.
- Continuing research will serve to create better understanding of long-term site productivity and the means necessary to attain it.

CHAPTER II

FOREST INSECTS AND DISEASES

IMPORTANT FOREST INSECTS IN THE BLUE MOUNTAINS

Introduction

Next to catastrophic wildfires, forest insects cause the most visible and dramatic losses of conifer trees, stands, and sometimes kill substantial numbers of trees in entire drainages in northeast Oregon and southeast Washington. Forest damaging insects occupy diverse habitats, ranging throughout the Blue Mountains in virtually every vegetation series represented.

We have identified eight major insect pests affecting resources in the Blue Mountains, these are: Western spruce budworm, Douglas-fir tussock moth, mountain pine beetle, Douglas-fir beetle, spruce beetle, fir engraver, western pine beetle, and pine engraver. This section will analyze in detail seven of these eight major insect pests. The eighth, the pine engraver, will be discussed only briefly.

A comprehensive analysis of each of these major forest insects will include detailed discussions of (1) hosts and community; (2) biology; (3) historical trends in the Blue Mountains; (4) stand conditions under which they occur; (5) occurrence within the Blue Mountains; (6) suppression of outbreaks; (7) impacts and effects on resources; (8) hazard -or risk- rating methods; (9) population dynamics or damage simulation models; and (10) pest management options or recommendations. A final section will include literature cited. The analysis was conducted based on experience and observations of the author; opinions, research, and recommendations of pest management practitioners and research entomologists in the Northwest; review of pertinent published literature and unpublished reports; and evaluation of responses to a questionnaire by various specialists representing a variety of resource disciplines from all Ranger Districts on the Malheur, Umatilla, and Wallowa-Whitman National Forests.

The management options presented in this chapter are considered to be the most effective means of minimizing pests and reducing pest-caused damage. Concerns for other resources and values will often require that these options be modified, perhaps reducing their effectiveness. The options presented in here must be considered as part of the integrated resource management process based on local objectives.

It is important to note that not all damage or mortality resulting from insect infestations is bad, nor is it always undesirable. Insects play a key role in providing natural diversity in riparian areas and old-growth stands through the creation of dead and dying woody material which serves to enhance site productivity and promote species diversity and richness by providing new habitats for animals. Insects also help to increase the standing dead tree component of these stands which are important as habitat for snag-dependent wildlife species. Similarly, streams and creeks are enhanced by the formation of new pools, ripples, and habitat for aquatic vertebrate and invertebrate species as insect-killed trees eventually fall over into these water courses. The level of insect-related tree mortality which occurs under these circumstances is both acceptable and desirable, and in fact is a good indicator (and progenitor) of healthy riparian and old-growth ecosystems.

On the other hand, concern regarding insects arises when they increase to outbreak numbers, or when stands have developed to a state in which they are predisposed to potentially catastrophic insect damage. Both situations significantly threaten our ability to manage the resource in a way consistent with the Forest Plans. This is the current situation throughout much of the Blue Mountains, especially in regard to mixed conifer stands. Western spruce budworm and bark beetles are seriously damaging certain mixed conifer stands, which affects our ability to meet the Desired Future Conditions for big game wildlife habitat, timber production, old-growth, riparian, and other resources.

Spruce beetles have nearly depleted the Engelmann spruce components in many drainages on the north end of the Wallowa-Whitman National Forest over the past 10 years, and many riparian areas have been seriously damaged as a consequence. Other damage from insects will be described in subsequent sections.

Given existing forest conditions in the Blue Mountains, we firmly believe that Forest health degradation, and in particular, insect- and disease-caused damage will continue, and perhaps worsen, as time goes on. While the insect situation may temporarily improve as the current insect epidemics collapse, without major changes in stand conditions and modification of management practices over relatively large areas, stands will continue to be periodically subjected to major depredations by insects, because the conditions making them highly susceptible to attack have not changed. Moreover, forest disease problems will continue to worsen little-by-little each year as untreated disease centers expand in size, and are aggravated by management practices that do not fully consider forest health.

Many of the current forest health problems in the Blue Mountains, particularly in regard to recent insect epidemics, have developed through decades of changes in stands and ecosystems, that occurred as a result of applying the best information and knowledge of forest management available at the time. For example, for years Sanitation-Salvage recommendations for reducing losses of mature ponderosa pines to western pine beetle have been followed in some places with greater zeal than originally intended, or prescribed as necessary for adequate "risk" reduction, by resource managers in certain areas of the Blue Mountains and other areas throughout the West. Entomological and silvicultural research determined that the practice of selectively removing certain "high-risk" ponderosa pine in virgin stands offered the best practical way of reducing risks of attacks and buildup of western pine beetle. The result was significant losses of volume in this highly valued species. When Sanitation-Salvage was introduced in the late 1930's, the practice offered the best practical means to effectively manage western pine beetle populations in mature ponderosa pine stands, and is still appropriate today. Yet the practice of overcutting while applying Sanitation-Salvage, unbeknownst to the practitioners at the time, would be one of several activities that were partially responsible for the depletion of virgin stands of ponderosa pine and conversion of those stands to ones having greater susceptibility to defoliator attacks and disease infections, alike. These forest practices, coupled with effective fire suppression and exclusion decreased the dominant role of pines in stands and reduced natural sources of pine seed, so that true fir species had much greater probability of becoming established on sites previously dominated by pines and other seral species like western larch and Douglas-fir. With passing decades, changes in land and resource management gradually evolved as new knowledge and understanding was gained in forest biology, ecosystem function, and multiple-resource management, and as emphasis and demands for uses of public lands changed.

The management of lands and resources on National Forests continues to evolve, not only in regard to the emergence of new knowledge and methods, but especially in response to the changing, and oftentimes challenging, views and interests expressed by the public for resource outputs. Hence, the need to periodically review and update the National Forest Land and Resource Management Plans should be an on-going process, outside the normal lifespan of a single implementation period. However, changes in policy and resource management direction are not accomplished without risk. The relation of certain past management practices to current forest health conditions clearly reflects the risks that were assumed, whether consciously or not, in undertaking those practices; yet, with the degree of understanding that existed at the time, it was difficult, if not impossible, to know in advance where various practices would lead with regard to Forest health. Likewise, course adjustments that are made in the management of resources today, may lead to results different from what is desired or anticipated. It may take decades for the consequences of changes in forest management to become fully manifested. Hence, as with Forest Plan review, Forest health review should be an on-going process. Routine Forest health monitoring will be a key means of detecting untoward Forest health effects and changes in the future.

Regarding pest problems, it is also important to note that there were pest problems in antiquity, and they will continue in the future, regardless of management practices. The challenge will be to moderate as much as possible those conditions that exacerbate insect and disease problems, while balancing the needs for all resources, and achieving the Desired Future Conditions of the Forest Plans.

General Discussion of Forest Insects

Many insects cause damage that is not readily apparent. These insect pests feed hidden in the roots or bole of weakened, recent dead, and older dead conifer trees; in or on terminal leaders and lateral branch tips, developing buds or shoots, and on boles, branches, and roots of living trees; and in cones, reproductive structures, or seeds developing within cones. Losses from these pests sometimes affect the volume of recoverable wood fiber, structural soundness, or aesthetic quality of finished wood products; growth potential and form of trees; and supply of viable seed available for regenerating new stands. Though losses from these pests are important, they seldom cause mortality or damage over widespread areas, necessitating the need for suppression, except in the case of high-investment tree-improvement areas, e.g., evaluation plantations, seed orchards, and other seed production sites.

Other insects are much more damaging to conifers and visible to the observer, sometimes defoliating or killing trees over tens or hundreds of thousands of acres, and affecting to some degree nearly every managed resource on National Forest lands. Insect outbreaks are caused by a number of factors. The conditions or set of circumstances under which populations increase to outbreak levels vary from insect to insect. In the Blue Mountains, natural fire has been one of the greatest influences in shaping the vegetative communities of the region, and the exclusion of fire since about the turn of the century, coupled with selective harvesting practices of the past, have contributed to the development of many stands of highly susceptible habitat for certain forest insect pests. The resulting stand conditions have set the stage for many of the recent outbreaks of damaging insects in the Blue Mountains.

At the present time, western spruce budworm may be characterized as the most serious insect pest in terms of acres of forest land infested and resources damaged in the Blue Mountains. However, Douglas-fir tussock moth may soon be vying with budworm for that position if populations continue to increase. Figures II-1 through II-3 show the widespread occurrence of budworm in the Blue Mountains. During 1990, over 1.5 million acres of forested land in the Blue Mountains were defoliated at varying intensities by budworm (Fig. II-4).

The western spruce budworm and various other major insect pests affecting resources in the Blue Mountains occur at varying intensities (detectable in aerial surveys) on a total of 53 percent of the forested portions of National Forest lands (Fig. II-4). It should be pointed out, however, that some of these acres may overlap because the same acres may be infested by more than one insect pest, and intensities are variable. We have not been able to separate these overlapping acres from those on which only one insect pest occurs. Nevertheless, the important point here is that forest insects are damaging trees over hundreds of thousands of acres of forests in the Blue Mountains, and these various insects will affect our ability to meet the Desired Future Conditions for various resources described in the Forest Plans, as the following pages show.

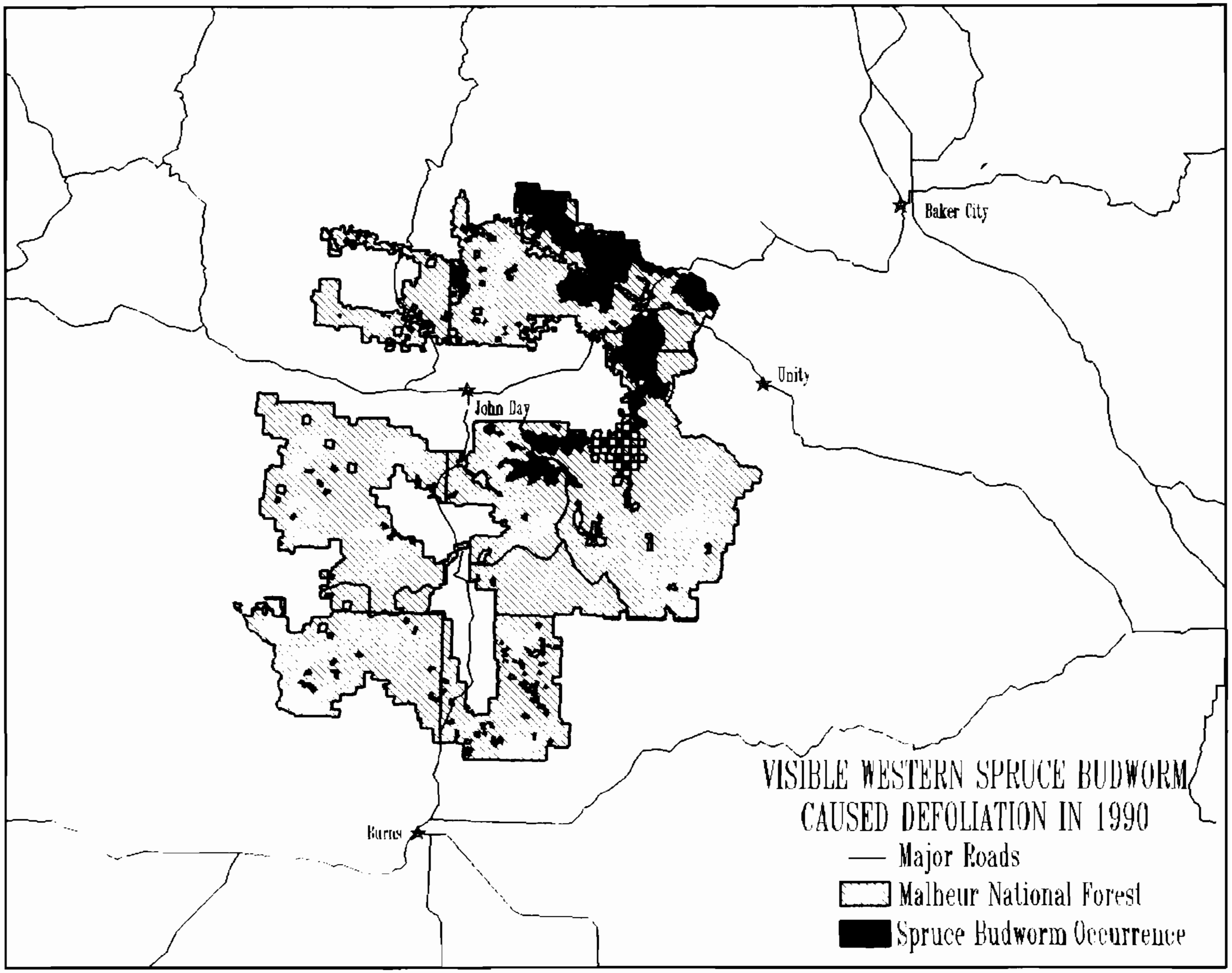


Figure II-1
Visible western spruce budworm-caused defoliation on the Malheur National Forest in 1990. (Based upon Aerial Insect Detection Survey data from 1990)

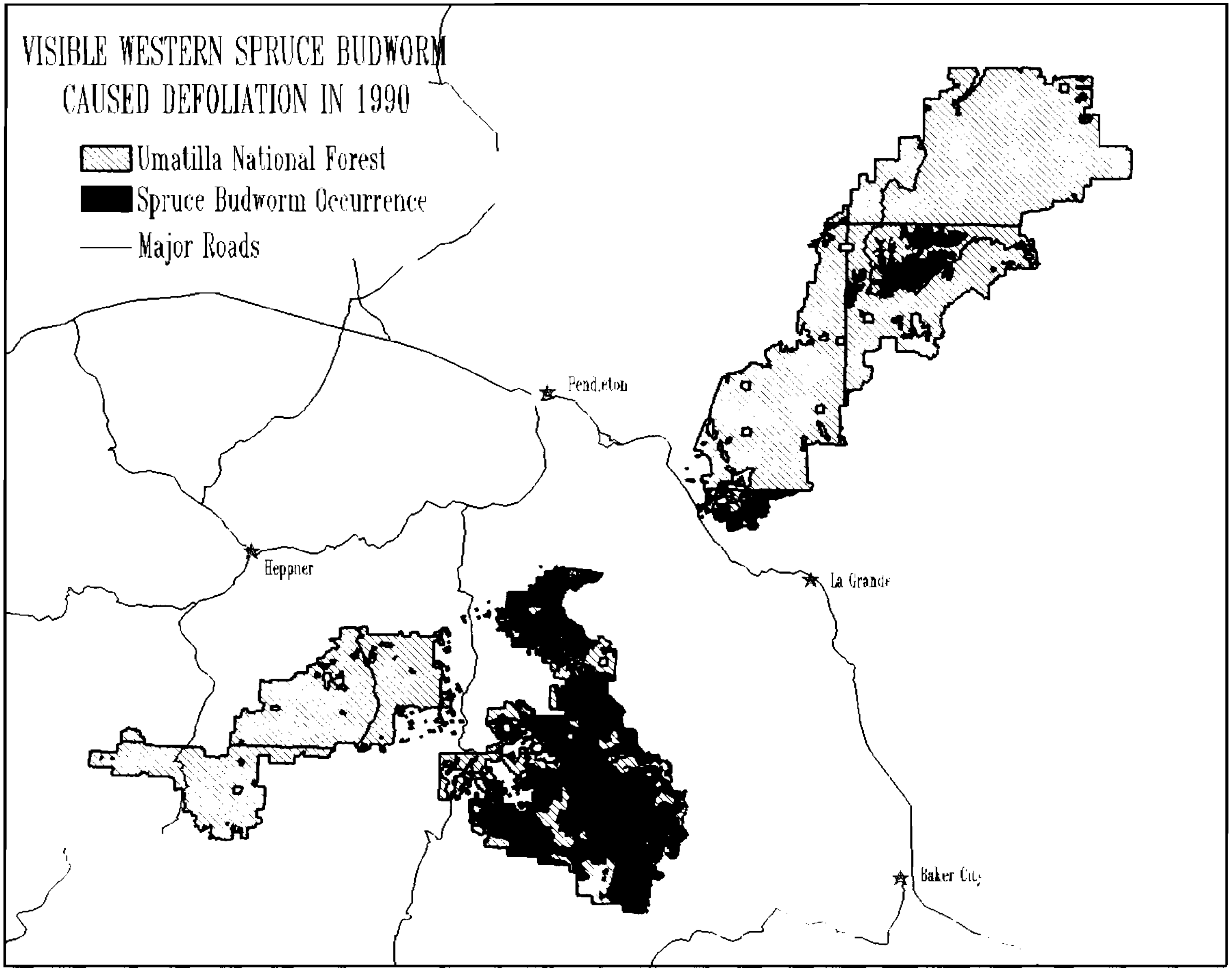


Figure II-2
Visible western spruce budworm-caused defoliation on the Umatilla National Forest in 1990. (Based upon Aerial Insect Detection Survey data from 1990)

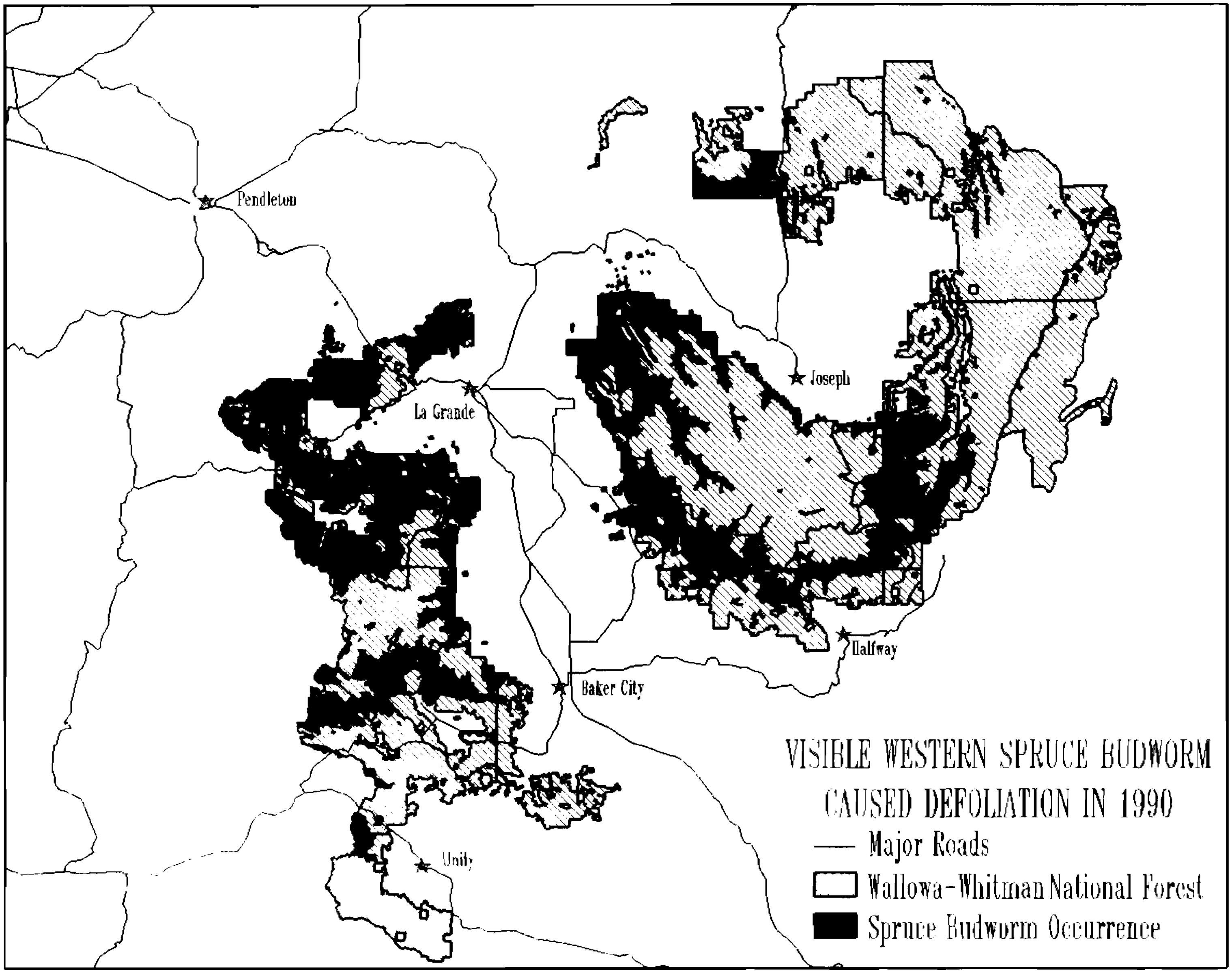
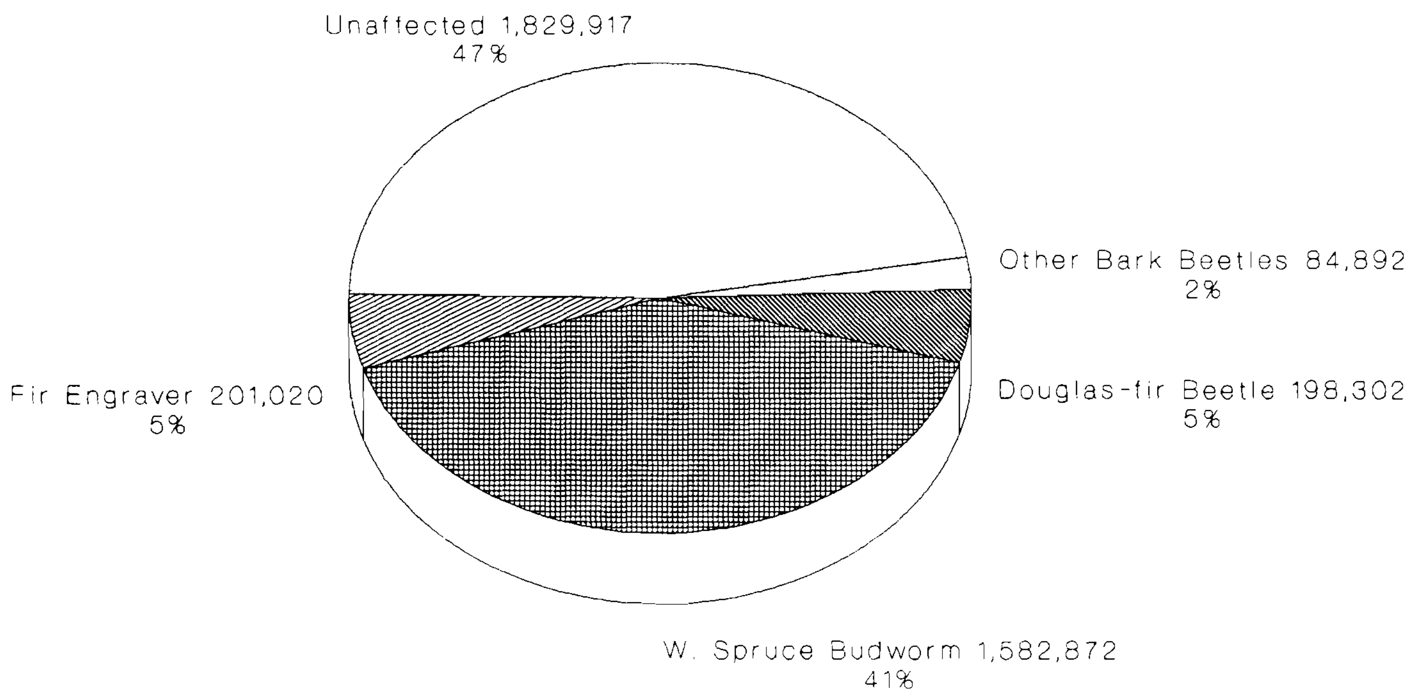


Figure II-3
Visible western spruce budworm-caused defoliation on the Wallowa-Whitman National Forest in 1990. (Based upon Aerial Insect Detection Survey data from 1990)

National Forest Acres In Blue Mountains With Visible Insect-caused Defoliation and Mortality in 1990



Infested acres are not additive because some acres are infested by more than one insect. Intensity varies by acre.

Figure II-4
National Forest acres in the Blue Mountains with visible insect-caused defoliation and mortality in 1990. (Based on Aerial Insect Detection Survey data from 1990)

Western Spruce Budworm (*Choristoneura occidentalis* Freeman)

Hosts And Community

The western spruce budworm feeds on a wide range of conifers throughout western North America, but only six are considered principal hosts; they include Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.), white fir (*A. concolor* (Gord. and Glend.) Lindl. ex Hildebr.), subalpine fir (*A. lasiocarpa* (Hook.) Nutt.), Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), and western larch (*Larix occidentalis* Nutt.). Budworms also feed on a number of other conifers, but these occasional hosts alone cannot support a budworm outbreak; hence they are considered nonhosts (Hermann 1987). Although larch is listed as a principal host and is sometimes damaged by budworm, it is not a very susceptible species in that it will not support the insect's complete life cycle (Carlson 1989).

In the Blue Mountains, western spruce budworm has a fairly broad ecological amplitude. It is found over a wide elevational range and is present to varying degrees in many different plant communities--from the warm and dry to cool and moist. Budworm occurs within several vegetation series, including mountain hemlock (CM), subalpine fir/lodgepole pine (CE/CL), grand fir (CW), and Douglas-fir (CD). Stands and forests composed of vegetation series containing moderate to high components of Douglas-fir, grand fir, or white fir are especially vulnerable to damage by budworm. The latter two species are relatively shade tolerant and in the interior of their range, in the absence of fire, replace less tolerant or intolerant associated species such as western larch, ponderosa pine, lodgepole pine, western white pine, and Douglas-fir as those stands develop toward climax. Feeding preference of budworm (and, therefore, population size) is generally related to shade tolerance, thus increasing as the degree of a host's shade tolerance increases (Schmidt et al. 1983). Development of shade-tolerant true fir species in the understory leads to multiple canopy layers of budworm host and consequent increased vulnerability of stands to damage by budworm.

In the cooler and wetter end of the grand fir series (CW), stands seem to be relatively less vulnerable to severe damage by budworm than are stands on the drier end of the grand fir type. This is even truer for the subalpine fir series (CE/CL), where the weather is often too cold and wet, and budworm is seldom found in the upper elevations of this series. Warm, dry habitats are most favorable for budworm (Wulf and Cates 1987).

Biology

Western spruce budworm is a univoltine insect (i.e. one generation per year) native to North America. The adult or moth stage usually emerges late in July or early in August. Females attract males for mating by emitting a sex attractant pheromone. Both sexes are winged, and dispersal in the adult stage is mediated to some degree by pheromones. Following mating, females soon begin laying eggs. Eggs are deposited in a shingled (layered) fashion along the underside of host needles, forming a mass of one to three rows wide. Each mass usually contain 25 to 40 eggs, but numbers may range from just a few eggs, to as many as 130 eggs per mass (Fellin and Dewey 1982). The eggs hatch within about 10 days.

Newly hatched larvae seek out shelters in branch scars, under bark scales, and among lichens on the limbs and boles of the host tree. There they spin a silken protective shelter (hibernaculum) within which they molt into the second instar. Larvae become dormant and overwinter within the hibernacula with the lowering of temperatures. Larvae break dormancy in the spring of the year when for several days temperatures exceed a 42 °F threshold. Thus, development of the budworm is closely tied to host tree phenology (Beckwith and Kemp 1984; Wagg 1958).

In host trees, both horizontal and vertical dispersal of larvae occur, resulting in the redistribution of budworm populations within and between both crowns and stands. Horizontal dispersal of budworm occurs during the first and second instars (Carolin 1987). Vertical distribution of larvae occurs mostly from the third instar on, when older larvae are sometimes dislodged from feeding sites through foliage disturbance and drop down to lower branches.

Budworm larvae commence initial feeding in the spring by mining in old needles, new pollen structures, and seed cones. When vegetative buds begin to swell and expand, larvae move from older needles and begin mining the buds. Late-emerging larvae move directly to opening buds upon exiting the hibernacula (Carolin 1987). The sequence of budworm feeding concludes with the budworm feeding on new foliage. As feeding progresses, larvae produce silken webbing to spin together cut, damaged, and new needles into shelters within which they feed. By summer these clusters of damaged and cut needles dry out and turn reddish or reddish brown, giving the branch tips a scorched appearance. Much of this damaged foliage is removed during winter rain and wind storms.

Larval development advances over several weeks of feeding, progressing until larvae reach their full growth from 30 to 40 days after entering buds (Carolin 1987). Pupation often occurs within the larva's last feeding web, but may occur in webs elsewhere on foliage. The pupal stage usually lasts about 10 days (Fellin and Dewey 1982), after which, the insect transforms to the adult moth stage, completing the generation.

History

Although native to North America, no budworm outbreak in the West was recorded until 1909 in British Columbia (Mathers 1931, Unger 1983). The first budworm outbreak in the Pacific Northwest (Oregon and Washington) was recorded in 1914 when specimens were reared from Douglas-fir at Ashland, Oregon (Lindsten et al. 1949). Most outbreaks that date between 1922 and 1946 were small and widely scattered. These early outbreaks subsided quickly and resulted in little or no damage (Dolph 1980; Stipe 1987). Outbreaks during the second half of the century in the Blue Mountains appear to be much more severe, causing more damage, and lasting longer than earlier infestations.

The first recorded outbreak in the Blue Mountains of northeastern Oregon occurred on the Umatilla National Forest in 1944, and eventually developed into a large-scale infestation involving the entire fir type throughout the Blue Mountains (Dolph 1980). It was after these and later large-scale infestations that the western spruce budworm became recognized as one of the most destructive forest insects in the West (Dolph 1980).

With the advent of the development of aerial-survey techniques during the late 1940's, entomologists had a means of rapidly detecting and mapping outbreaks over large areas of forested land. This allowed them to follow infestations over time. In addition, it allowed other insect infestations such as bark beetles to be mapped and their trends followed, e.g. bark beetle outbreaks that resulted from defoliator-weakened trees. The trend data on forest insects that we have today and is used in this report, comes largely from these aerial insect detection surveys.

The visible defoliation trend for budworm in the Blue Mountains, based on aerial survey data (Fig. II-5), shows a period of budworm defoliation between 1947 and 1960, followed by a relatively budworm-free period up to the start of the current budworm outbreak beginning in 1980.

In that year, a 2,080-acre infestation of budworm was detected near Cove, Oregon, on the Wallowa-Whitman National Forest, and another 260 acres of defoliation was mapped on the Umatilla. The following year, over 130,000 acres of budworm defoliation were detected on each of the Malheur and Umatilla National Forests, and over 42,000 acres were mapped on the Wallowa-Whitman. This outbreak in the Blue Mountains eventually increased to a peak of over 3.75 million acres of defoliation in 1986 (Fig. II-5). The defoliation trend has been downward since that time, but 1990 saw a resurgence of budworm-caused defoliation scattered throughout the Blue Mountains.

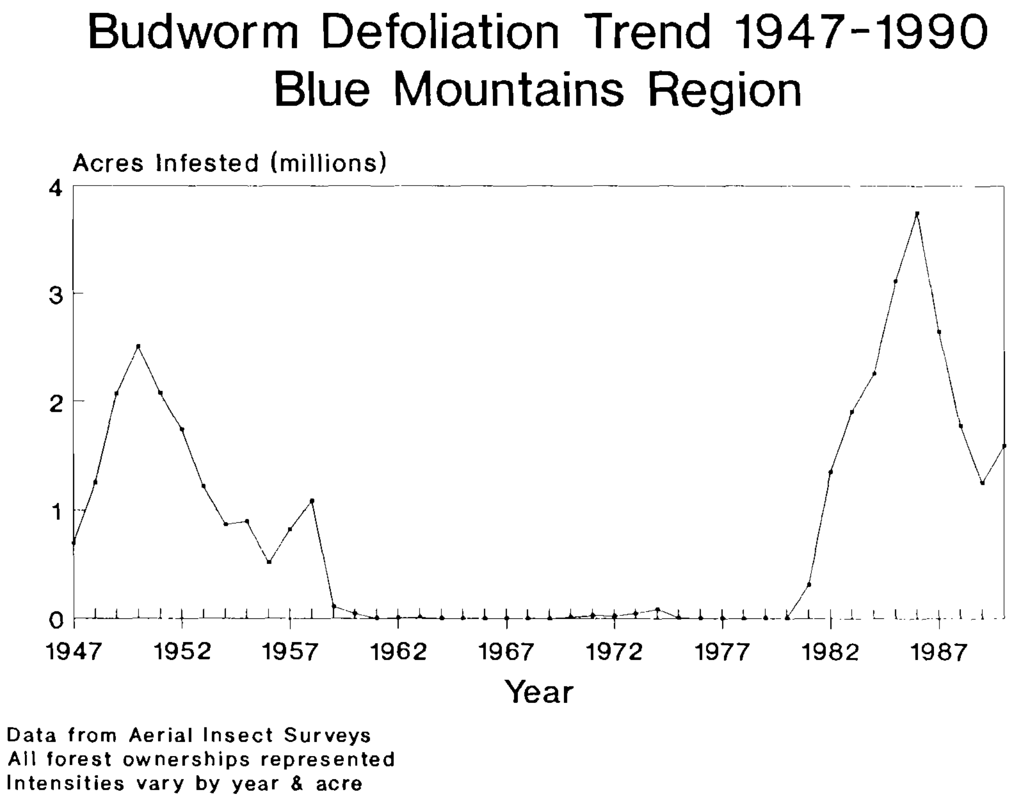


Figure II-5
Western spruce budworm defoliation trend from 1947 thru 1990 on forest lands in the Blue Mountains. (Based upon Aerial Insect Detection Survey data)

Stand Conditions

The frequency and intensity of western spruce budworm outbreaks vary greatly over the wide elevational and geographic range of host type communities and site conditions. Yet, despite site and stand differences, budworm populations seem to respond to similarities in the ecological conditions that govern the relative physiological stress in host trees (Wulf and Cates 1987). Detailed discussion of the site and stand characteristics that promote budworm outbreaks has been thoroughly treated elsewhere (cf. Carlson 1987; Carlson and Wulf 1989; Wulf and Cates 1985; and Wulf and Cates 1987). The factors that affect budworm habitat, and the conditions that bring about stress on budworm host trees are briefly summarized in the following paragraphs.

Occurrence of outbreaks of budworms throughout the West are generally related to the dramatic increase in budworm habitat since the late 1800's and early 1900's. This has come about through widespread changes in forest condition associated with early harvesting practices, fire suppression, and the far-ranging establishment of an understory of shade-tolerant budworm host species (Carlson and Wulf 1989; Schmidt 1985; Schmidt 1987; Swetnam and Lynch 1989; Wulf and Cates 1987). With the increase of true fir components in stands that in times past were dominated by seral, shade-intolerant, and more fire resistant species (e.g. ponderosa pine, western larch, and Douglas-fir), the stage was set for budworm outbreaks. Furthermore, damaging outbreaks will continue to develop in the future so long as present budworm habitat conditions exist and are promoted by certain forest management practices. While species composition of stands and forests sets the stage for future outbreaks, several other factors interact to affect forest and stand susceptibility. Carlson (1987) succinctly described these factors and the roles they play in the following (It is important to note that these factors are based on observation and limited research data from the northern Rocky Mountains. While they may generally hold true for the Blue Mountains, some discrepancies do exist. These discrepancies are noted by the parenthetical closures.):

Host Phenology--Synchronization of budburst with spring larval emergence is important to the budworm. Generally, host species on which buds break after larval emergence are less susceptible than species that have earlier budburst. For example, Douglas-fir growing in association with grand fir on grand fir habitats break buds later than grand fir and are relatively nonsusceptible. (This may be true for the intermountain and Rocky Mountain west, but Douglas-fir throughout the Blue Mountains can be quite susceptible).

Stand Composition--Stands composed mostly of lodgepole pine, ponderosa pine, or other species not considered primary hosts of the budworm are seldom attacked. In stands composed mostly of host trees--particularly Douglas-fir and the true firs--susceptibility increases with the proportion of shade-tolerant species present. Pure stands of shade-tolerant grand fir are more susceptible than stands composed of a mixture of Douglas-fir and grand fir. (However, mixed conifer stands in the Blue Mountains can be heavily infested.) Shade-tolerant species also incur greater injury than shade-intolerant species for a given budworm density. Thus, in mixed Douglas-fir and grand fir stands, loss of biomass is less than would be found in a pure grand fir stand. Similarly, in Douglas-fir climax communities, where Douglas-fir is the most shade-tolerant species, injury is greatest in pure stands.

Stand Density--Susceptibility to the budworm increases as the density of host species increases. Thick, dense stands of true firs or Douglas-fir have a tremendous amount of foliage biomass and provide budworm with ample substrate of good quality. Larval dispersal loss is reduced in dense stands because the nearly continuous crown cover prevents larvae from falling to the ground, where they are prey for ants, spiders, and other predators. Heavy budworm feeding in dense stands can cause significant injury. These stands usually are under extreme competition for moisture, nutrients, and light. Food reserves for the stand may be limited, and any additional stress, such as insect feeding, may result in severe damage. Heavy defoliation can cause extensive top-kill, mortality, and growth loss in overstocked stands. (Thinned stands can be heavily infested by budworm also, even those which are thinned several years prior to outbreak.)

Height Structure--Multistoried host stands are better habitat for budworm than are even-aged, one-storied stands. Intermediate crown layers tend to reduce loss during larval dispersal and increase food available to the budworm. During an outbreak, large larvae (fifth and sixth instars) often deplete foliage on large trees and spin down in search of additional food, frequently landing on intermediate crown layers, where they can then complete their life cycle. Further, the lower canopies of multistoried stands usually are composed of shade-tolerant conifers, the preferred hosts of the budworm.

Stand Vigor--Fast-growing, healthy stands are less susceptible than stagnated, stressed stands. Foliage quality in stressed stands is more favorable to the budworm and tends to promote insect survival. Stressed sites are less capable of supplying water and nutrients to trees. Nutrient availability and cycling may be a major influence in causing stress. Ultimately, starch reserves, which are important in postoutbreak recovery, usually are limited in stressed stands. (Experimental proof that foliage quality is directly related to insect survival is lacking.)

Stand Maturity--Even-aged stands 1 to 20 years old are low in susceptibility because they offer limited substrate and very little opportunity for budworms to lay eggs. Larvae that do disperse to developing young conifers are easy prey for ants, spiders, and other predators. Susceptibility increases as stand age increases. Stands 40 to 60 years old tend to have high foliage biomass and have developed dominance classes. The budworm tends to do well in stands where an irregular canopy creates warmer, drier conditions for developing larvae. Other conditions remaining constant, vulnerability generally increases with stand age.

Stand Size--Host stands of small acreage isolated in nonhost types are not likely to be infested by budworms. (However, in the Blue Mountains there are numerous examples of small, isolated host stands being infested by budworm, e.g., farm woodlots). Conversely, large, contiguous blocks of a host type, such as may occur throughout a drainage, can be highly susceptible. Because large acreages of host types tend to support increasing budworm populations, injury to infested stands can be expected to increase also. Furthermore, stands that in all other characteristics would be classified as susceptible may really not be subject to attack if they are not near substantial acreages of host type.

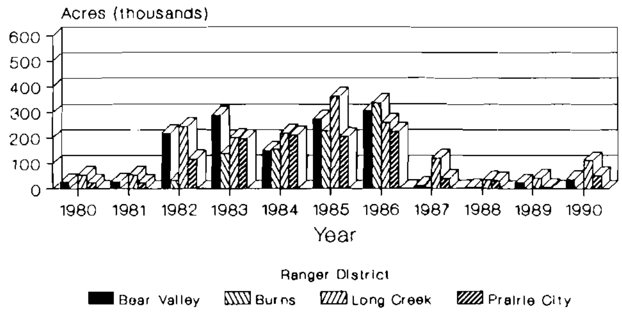
Climate and Topography--Stands in geographic areas with a relatively warm, dry, spring climate are more susceptible and incur more injury than stands in wet, cold areas because budworm larval development is favored by warm, dry conditions. Topographic conditions that promote warm and dry stand conditions also favor the budworm. For example, stands on south-southwest aspects of moderate slope are much more susceptible than stands on north aspects.

Occurrence

The occurrence of outbreaks is determined by stand conditions which provide favorable habitat for budworm, mediated by weather factors which promote rapid larval development and high survival, and acts in conjunction with the degree of influence exerted by natural enemies on budworm populations. This section is a brief discussion of trend and distribution of the current outbreak, and includes also a discussion of factors which influence the termination of outbreaks.

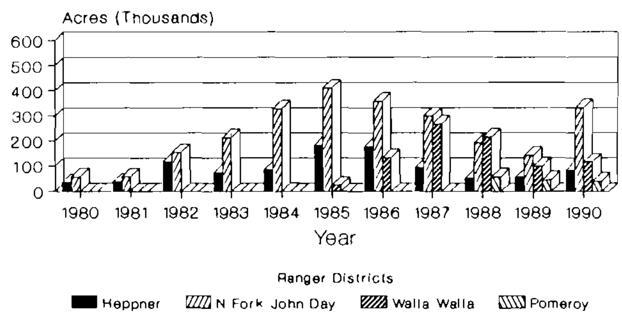
The trend of the current Blue Mountains budworm outbreak which began in 1980, has been downward since about 1986. It appeared from all estimates that budworm populations in the Blue Mountains were on the decline. The spring of 1990, however, proved otherwise. Budworm populations resurged throughout the Blue Mountains, and upswings in the number of acres defoliated were evident on nearly all districts on the Malheur, Umatilla, and Wallowa-Whitman National Forests (Fig. II-6). It is speculated that weather conditions (a fairly mild winter and a favorable spring) enhanced distribution, survival, and development of emerging larvae. This, coupled with another season of abnormally low precipitation which continued to stress trees already weakened by years of budworm defoliation, likely contributed to the resurgence of budworm populations. Thus, despite the best attempts, it is becoming increasingly difficult to estimate the trend in budworm populations, as witnessed by the 1990 resurgence.

Acres With Visible Budworm Defoliation
Malheur National Forest



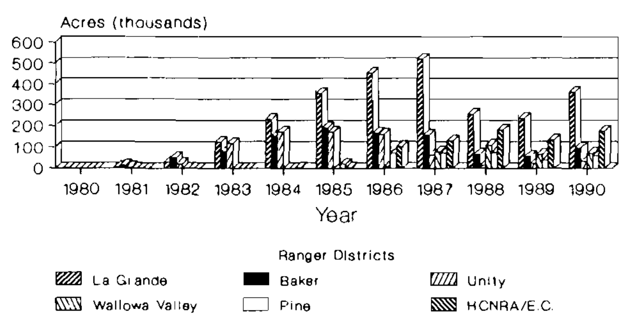
Suppression Project Bear Valley RD 1982
Suppression Project 1983, 1987
Intensity varies by year & acres

Acres With Visible Budworm Defoliation
Umatilla National Forest



Suppression Project Heppner RD 1982 & 83
Suppression Project Walla Walla RD 1986
Intensity varies by year & acres

Acres With Visible Budworm Defoliation
Wallowa-Whitman National Forest



Intensity varies by year & acres
USFS lands only
Incomplete data for wilderness

Figure II-6
Acres with visible western spruce budworm-caused defoliation on National Forests in the Blue Mountains from 1980 thru 1990. (Based upon Aerial Insect Detection Survey data)

Western spruce budworm has no predictable pattern or trend that can be reliably used to gauge future epidemics. The record for early outbreaks indicates they were small, scattered, and not very damaging. Subsequent outbreaks are much more widespread, longer-lasting, and have caused significant damage. Some outbreaks in other regions of the west have gone on for 35 years or longer. Other locations have had shorter and more intense outbreaks. It is probable that the current Blue Mountains outbreak will subside when the current drought cycle ends. Wulf and Cates (1987) suggest that infestations subside when internal competitive stress between host trees is relieved and immigration falls off, thus allowing complexes of natural enemies (which regulate low levels of budworm) to become reestablished, and creating a mass starvation situation for young larvae. Another condition which has been credited with short-term reductions of budworm outbreaks is adverse weather (Fellin 1985). Early spring frosts which kill emerging young larvae and destroy new buds and succulent new foliage can dramatically reduce budworm populations to endemic levels.

However, it should be noted that no single natural control factor, no matter how important to the population dynamics of budworm, can, of itself, prevent or reduce population resurgences when climatic and forest-stand conditions are favorable to the insect (Fellin 1965).

Suppression

During the period of 1948 through 1951, experimental field trials were conducted on the Umatilla and Wallowa-Whitman National Forests to identify chemical insecticides that could be effectively used against western spruce budworm (Stipe 1987). The pesticides tested included DDT, toxaphene, and dieldrin. With successful test results from DDT, pest managers quickly adopted this insecticide over the others for operational use in reducing budworm populations; hence, DDT was used annually between 1950 and 1955 to treat some 3.09 million acres on the Umatilla, Wallowa-Whitman, and Malheur National Forests. These control operations were deemed successful in reducing budworm populations.

The first two years after the final treatment with DDT in 1955, the number of acres defoliated by budworm increased, but populations dropped dramatically in 1959 and remained relatively low for a number of years.

Suppression of budworm populations in the Blue Mountains with insecticides commenced again during the second year of the current outbreak. In 1982, the chemical insecticide, carbaryl (Sevin 4-oil), was sprayed over 169,354 acres on the Malheur and Umatilla National Forests. An additional 9,195 infested acres on the Malheur were treated with the chemical insecticide, acephate (Orthene) in 1982 (Hostetler 1983). The following year, 524,561 budworm-infested acres were treated. Carbaryl was applied to 501,994 of the acres, mexacarbate was applied to 10,095 acres, and the biological insecticide, *Bacillus thuringiensis* (*B.t.*), was used to treat 12,472 acres (Bridgwater 1984). A study by Torgersen et al. (In review) of selected areas treated with carbaryl in 1983, showed the suppression project to have short-term benefits. However, by the third year after treatment, there was a budworm resurgence to levels in excess of those in untreated areas. A continuing pattern of greater budworm numbers in the formerly treated areas, as compared to untreated ones, persisted for several subsequent years.

Further evaluation of the use of *B.t.* against budworm on the Ochoco National Forest in 1984 indicated that *B.t.* was a viable alternative to chemical pesticides for the suppression of western spruce budworm (Ragenovich 1988). Since 1984, all treatments (experimental and operational) of budworm conducted in the Blue Mountains by the federal government involved the use of *B.t.* In 1985, 40,979 acres were treated with *B.t.* in an operational evaluation on the Malheur National Forest. In 1987, a total of 85,922 acres were operationally treated on the Forest, while another 360 acres (near Burns) were treated with *B.t.* in a field test (Ragenovich 1988).

The Umatilla National Forest conducted a pilot test of undiluted, water-based *B.t.* products on 38,565 acres in 1988, and treated an additional 19,143 acres in an operational suppression project adjacent to the pilot project treatment blocks (USDA Forest Service 1988). A second operational suppression project was conducted on the Forest near Tollgate, Oregon, during 1988. The Tollgate project applied *B.t.* to 106,663 acres (USDA Forest Service 1988 unpubl.).

The latest treatment of budworm infestations in the Blue Mountains was on the Wallowa-Whitman National Forest near Halfway, Oregon in 1989. The Forest Service conducted a pilot test with *B.t.* on 5,189 acres (J. Hadfield, personal communication, November 28, 1990). From 1948 through 1989, a total of over 4.6 million budworm-infested acres have been treated in the Blue Mountains of northeast Oregon.

Some state and private lands within the Blue Mountains have been sporadically treated to reduce budworm populations over the years. The total number of acres treated, though not known, is believed to be small in comparison to the amount of land treated by Forest Service-conducted projects.

Another important aspect of chemical suppression of budworm in the Blue Mountains has been the use of acephate implants in tree improvement programs. Between 1984 and 1991, over 9,200 trees on National Forest lands in the Blue Mountains were implanted with the systemic insecticide, acephate (Vicky Erickson, personal communication, March 21, 1991). The purpose of the treatment was to protect from defoliation by spruce budworm selected parent trees included in tree improvement programs, their developing cone crops, and surrounding pollen donors. The majority of the treated trees were Douglas-fir (83%), with lesser amounts of western larch (14%) and white/grand fir (3%) receiving treatment. The cost of this treatment averaged $18.00/tree, with about half of the cost being the cost of the acephate-containing capsules (Acecaps). These treatments have been very effective, but the timing of treatment is critical: implants must either be applied in the late fall after trees are dormant, or in early spring at least 2-3 weeks prior to vegetative budbreak. It has been suggested (Erickson, personal communication, 1991) that the cost of acephate implantation is low enough that they could probably be used to protect seed sources in seed tree or shelterwood stands as well.

Effects

Budworm outbreaks have varying effects on a wide range of resource values. The timber resource is affected through a weakening of trees caused by loss of foliage which leads to growth losses and predisposes trees to attack by bark beetles. Other impacts include top-kill, stem deformity, outright mortality, and loss of cone and seed production. On the positive side, by thinning stands through the killing of overstocked, suppressed understory firs and the weakening of larger diameter intermediate and overstory trees that are later killed by bark beetles, some suggest that budworm is a natural regulator of stand density and forest productivity. Further, the budworm acts as an agent of diversity by allowing more sunlight to reach the ground and promoting establishment and growth of a wider range of forest vegetation, especially the shade-intolerant pines and larch that are actually better adapted to these sites. Furthermore, budworm feeding enhances nutrient cycling by adding nitrogen and other elements back into the soil through nitrogen-rich fecal pellets and parts of needles that are clipped off during feeding.

Another forest resource that can be affected by budworm action is the wildlife component. Extreme loss of crown biomass from budworm defoliation can cause significant decreases in the quantity and/or quality of coniferous overstory that are important for big game thermal cover, hiding, and escape, thus adversely affecting the use of defoliated areas by wildlife populations. On the other hand, the opening up of dense stands improves forage production capability which may benefit both domestic animals and wildlife populations. Scenic vistas are also influenced by the degree to which conifers are defoliated. Light feeding by budworm may not be noticeable to the casual observer; whereas, to some individuals, heavy feeding creates a visual impact and alters the scenic beauty of an area. From a visual standpoint, damage from budworm feeding is transient during the early stages of an outbreak. Foliage that has been damaged by budworm turns red in the summer as it dries, and is very noticeable. After winter wind and rain storms remove the dead foliage from the trees, many people may not even be aware of the past budworm feeding in an area. Conversely, crowns that become thin from repeated foliage loss, as happens later in an outbreak, are very recognizable to some. Whether foliage loss due to budworm feeding adversely affects the visitations of defoliated areas by recreationists and hunters, is not known. Another important effect of even minor defoliation is the loss of value to Christmas tree growers that have lands adjacent to budworm-infested National Forest lands.

The threat of wildfires may also be increased due to a budworm outbreak. Infestations of budworm and other insect pests have contributed to fuel loads and increased the rate of fuels accumulation. In the event of wildfire, the increase in larger fuels on the ground, which could result from budworm-caused mortality and budworm defoliation-mediated bark beetle-caused mortality, could slow fireline construction and present greater risk to fire crews from the possibility of falling snags.

Soil properties and water quality and quantity are not usually adversely affected by budworm defoliation. While comprehensive studies on these resources during a budworm outbreak are apparently lacking, some inferences can be drawn from experience with defoliation by Douglas-fir tussock moth in the Blue Mountains. Statistically significant increases in streamflow were noted during a tussock moth outbreak only when defoliation exceeded 25 percent (Helvey 1978), and no significant difference in water quality was found between affected and unaffected watersheds on the Umatilla National Forest (Hicks 1977). Because budworm defoliates stands much more gradually than tussock moth, other unaffected vegetation will increase in density as canopies become more open from defoliation, and vegetation will intercept and use a greater portion of available moisture (USDA 1989).

Hazard Rating

Hazard rating is one means of setting priorities for treatment of budworm-susceptible stands. Presently, there are five different methods of hazard rating stands for budworm susceptibility in use: Aerial surveys, a climatological regression model, photo interpretation with regression modeling, an empirical site-stand regression model, and a generalized indexing model. In the interest of space, these methods will not be described here. The reader is referred to Brooks et al. (1985) for a detailed description of each.

Although these methods have not all been tested or used in the Blue Mountains, some undoubtedly have promise as a means of helping to identify high-hazard stands, and establishing treatment needs and priorities. We have some doubts whether certain present methods of hazard rating (e.g., aerial surveys) can really be done accurately enough, or have the resolution necessary, to hazard rate stands. It is probably advisable to avoid attempting to use this or other methods which are not based on precise empirical data, or do not have statistical bases.

Models

The U.S. Department of Agriculture, Forest Service has developed the Budworm Modeling System, a system of computer programs that is useful to simulate many aspects of budworm dynamics and budworm-caused damage on stand growth (Crookston et al. 1990). The system contains four computer programs:

Budworm Dynamics Model--this model estimates budworm population changes, foliage growth, budworm growth, feeding, and subsequent defoliation dependent on several site, stand, foliage, and weather conditions (Sheehan et al. 1987; Sheehan et al. 1989). The Budworm Dynamics Model simulates budworm population dynamics on up to thirty stands at a time.

Prognosis-Budworm Dynamics Model--this linked model can simulate budworm-stand interactions for only one stand at a time, but for much longer time periods because the Prognosis Model simulates tree growth.

Prognosis-Budworm Damage Model--this model is like the Prognosis-Budworm Dynamics Model but does not contain the budworm population dynamics component. With user-supplied estimates of budworm-caused defoliation, the model simulates tree growth and mortality under the given defoliation conditions.

Parallel Processing-Budworm Dynamics Model--presently, this model component is not available but is planned for future release. It will represent the growth of several stands in parallel, and will provide a means for the multistand Budworm Dynamics Model to simulate interactions, including tree growth and insect dispersal between stands, over long time periods.

Management

Management of budworm infestations requires a thorough evaluation of the insect population, its potential for damage, the consequent effects on the resources of the area, and the management objectives and direction for the area. Decisions regarding budworm management are further complicated by various factors, some of which are: The diversity of geography and climate; the variety of tree species that serve as hosts: variations in the insect--its behavior and complex relations with host trees; land ownership; and physiography (Fellin 1985).

In the broadest sense, management options can be grouped into the following three categories: (1) Do nothing; (2) direct suppression with chemical or biological insecticides; and (3) use silvicultural methods to manipulate the budworm's habitat. Each has advantages and disadvantages, and addresses different strategies. In general, direct suppression gives short-term results, whereas, silviculture has the potential for long-term management of budworm populations. These options all fit into the strategy of integrated pest management, which has been adopted as Forest Service policy for coping with destructive forest insects (Stark and Wright 1987).

Although a number of insecticides are registered and available for use against western spruce budworm including acephate, *Bacillus thuringiensis* (*B.t.*), carbaryl, malathion, methomyl, naled, and resmethrin (Hamel 1983), only Carbaryl and *B.t.* are recommended in this Region (USDA 1989).

Silvicultural treatments can be used to reduce forest and stand susceptibility to budworm. The following are the silvicultural practices described by Carlson and Wulf (1989) that will reduce budworm habitat and sustain vigorous forest growth:

- o Strive for stand diversity in species composition by favoring seral trees and removing or otherwise discriminating against the most shade-tolerant host species.

- Regulate stand density through appropriate release cuttings and thinnings to improve and maintain tree vigor and stand growth. Do not thin stands with large budworm populations during an outbreak, however. When this has been done in the Blue Mountains, disastrous results followed. Large budworm populations were concentrated on residual trees and invariably stripped the foliage from them, killing many of them.

- Create and maintain even-aged stand structures by using even-aged regeneration systems, followed by periodic low and crown thinnings.

- Promptly remove all overstory trees once regeneration is established in seed-tree and shelterwood cuttings.

- Improve stand vigor by removing diseased, heavily infested, or otherwise unhealthy trees in all cuttings.

- Capitalize on phenotypic and genetic resistance to budworm by selecting the most heavily defoliated trees for removal. Retain the lightly or nondefoliated trees for seed trees; direct cone-collection programs to those phenotypes.

- Regenerate host stands to less susceptible species at or before biological maturity, as indicated by the culmination of mean annual growth.

- Diversify the host forest by creating seral stands in currently homogeneous areas of late successional or climax host stands.

- Use degree-day or shoot elongation techniques to time sampling of western spruce budworm (Wickman 1988).

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Douglas-fir Tussock Moth (*Orgyia pseudotsugata* (McDunnough))

Hosts and Community

Douglas-fir tussock moth has three major, and one minor host tree species. The principal hosts are: Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.), and white fir (*A. concolor* (Gord. and Glend.) Lindl. ex Hildebr.). Subalpine fir (*A. lasiocarpa* (Hook.) Nutt.) is a minor host species (Balch 1932). In addition, larvae have been found feeding on a number of other conifers, usually after the preferred hosts have been stripped (Balch 1932; Eaton and Struble 1957; Wickman et al. 1981).

Within the Blue Mountains, the tussock moth may be present in stands wherever its hosts occur. Vegetation series that host tussock moth include mountain hemlock (CM), subalpine fir/lodgepole pine (CE/CL), grand fir (CW), and Douglas-fir (CD). While Douglas-fir and grand fir components in these stands may be seriously damaged or killed by tussock moth, understory trees of all species are often fed on by larvae that drop from the host overstory when populations are overcrowded (Johnson and Ross 1967; Beckwith 1978). Underbrush vegetation may also be fed on (Keen 1952).

Biology

The Douglas-fir tussock moth is a native defoliator of conifers (Douglas-fir and true firs) in western North America. It is univoltine, passing through four stages to complete the generation: Egg, larva, pupa, and adult.

Adult moths emerge from their cocoons from August through early September. Female moths have reduced wings that are non-functional for flying, and, therefore, differ in appearance from the winged, flying male. Upon emergence, females cling to the outside of the cocoon and emit a pheromone to attract male moths for mating. Adults mate on the cocoon from which the female has emerged, whereupon the female deposits a mass of fertilized eggs that number from 150-250 per mass. This egg mass is covered with a frothy substance which, when dry, envelops the eggs with an insolating layer containing many embedded hairs from the female moth's body. Tussock moths overwinter in these egg masses, usually located on the underside of small branches scattered throughout the tree crowns. But in heavy infestations, they may be concentrated on the lower parts of trees, on trunks and undersides of larger limbs, or on objects some distance from the tree (Wickman et al. 1981).

In late spring, after the host tree has begun new growth, eggs hatch and larvae seek out the new foliage for feeding. Budburst and egg hatch, and subsequent larval development are closely related to accumulated degree-days (Wickman 1976). New foliage is essential for early larval growth, but as larvae grow and deplete the supply of new needles, they shift to feeding on older needles (Beckwith 1976; Mason and Baxter 1970).

Wind dispersal of young larvae is an important means of population redistribution. The tiny, newly hatched larvae are covered with hairs. Their light weight and hairy body allows them to be carried some distance, usually (ca. 200 m.) by wind (Mitchell 1979). Because concentrations of wind-dispersed larvae sufficient to initiate new outbreaks are seldom reached, outbreaks are believed to develop in place (Mason and Luck 1978; Mitchell 1979).

On a host tree, larvae crawl to the top or to the ends of branches and feed on the new foliage. The first two instars of tussock moth feed exclusively on the underside of the succulent, new needles. This feeding damages the needles, causing them to dry and turn red-brown by midsummer. Faded foliage at the tops of trees is often the first sign of tussock moth infestation. As larvae grow, they molt four or five times through several more instars, while progressively consuming more foliage with each successive molt.

Mature larvae are quite hairy and colorful. Two long, dark pencil tufts of hair resembling horns are located just behind the head; a similar but longer pencil tuft protrudes from the opposite end. Four dense, buff-colored tussocks adorn the front-half of the caterpillar, along the top side. The rest of the body, except the legs and head, is covered with short hairs radiating from red, button-like bumps. These larval body hairs are barbed and cause a skin rash on sensitive individuals. These hairs are used to cover the cocoons and egg masses and may serve as protection from predators.

After completing the last instar, the larva makes a thin cocoon of silken webbing mixed with body hairs to pupate in. There it transforms from the larva stage to an adult from late July to September. The adult moths emerge from cocoons 10 to 18 days after entering pupation and the females immediately mate and lay eggs.

Periods between outbreak are characterized by very low population levels, and the tussock moth is rarely observed in the forests. Under favorable environmental conditions, reproductive success by moths results in a rapid increase in populations beyond the ability of natural enemies to hold the population in check, giving rise to an outbreak.

Many factors are responsible for natural mortality in tussock moth populations, including insect parasites and predators, avian predators, spiders, vertebrate predators, starvation from depletion of food supply, and a disease caused by nucleopolyhedrosis virus. Tussock moth populations usually collapse to very low densities after 1-3 years of heavy defoliation. Nucleopolyhedrosis has been reported as one of the important factors in these natural collapses (Dahlsten and Thomas 1969; Evenden and Jost 1947; Mason and Thompson 1971; Morris 1963; Wickman et al. 1973).

When virus-infected larvae die, internal tissues laden with virus and the integument (exoskeleton) break down. Larvae killed by the virus often hang upside down, attached to the branch by only the anal prolegs. Eventually their grip is relaxed, or disturbance of the branch ruptures the fragile, flaccid insect cadaver, causing the larva to fall to the branches below, splattering virus over the foliage. The virus disease spreads through the population as other tussock moth larvae feed on the contaminated foliage, die, and contaminate more foliage. The polyhedral inclusion bodies (virus particles, contained in a protein matrix) eventually are washed by rains and snow melt from the foliage into the soil where it can persist for decades (Thompson and Scott 1979; Thompson et al. 1981).

History

The Douglas-fir tussock moth has periodically caused extensive damage and tree mortality to coniferous forests in western Canada and the United States. Outbreaks usually last 3 years, following a typical pattern in which the insect population goes through a release phase (rapid increase in numbers resulting in visible defoliation); a peak phase (maximum insect density reached); followed by a decline phase (rapid decline in insect numbers due to reduced food availability and increased mortality through the actions of natural enemies and disease); and ending with a postdecline phase, by which time the collapse of the population is completed (Wickman et al. 1973).

Outbreaks have typically occurred simultaneously over a region-wide or west-wide basis. Some outbreaks during the 1970's, for example, occurred in synchronous fashion in areas of British Columbia, Washington, Oregon, Montana, Idaho, California, and New Mexico (Shepherd et al. 1988). In the Blue Mountains of Oregon, some outbreaks of tussock moth have affected areas on the Ochoco

National Forest, however, most of what is reported here pertains to the Malheur, Umatilla, and Wallowa-Whitman National Forests only.

The first reported tussock moth outbreaks in the Blue Mountains came in 1928. These were considered minor outbreaks; one occurred on the north half of the Wallowa National Forest on the Minam Division, and the other on the Malheur National Forest in the vicinity of Seneca, Oregon. Both outbreaks collapsed in 1929. The duration and sizes of the outbreaks are not known. Tussock moths killed a considerable amount of timber on the Wallowa National Forest, but damage on the Malheur was largely restricted to top killing (Buckhorn 1948).

Another early outbreak was discovered on Rudio Mountain, Malheur National Forest, in 1937. This outbreak involved nearly 80,000 acres and killed a large amount of timber before it collapsed in 1939. Approximately a third of the white fir and Douglas-fir trees died in the most heavily defoliated area of the outbreak. During the same period another (less severe) outbreak was observed north of Rudio Mountain near Spray, Oregon on the Umatilla National Forest (Keen 1952). This infestation subsided in 1940 (Buckhorn 1948; Shepherd et al. 1988). During the summer of 1939 some undetermined factor caused heavy mortality among the large larvae (probably virus). Consequently, the 1939-40 generation was very light and caused no noticeable defoliation in 1940.

The trend of Douglas-fir tussock moth in the Blue Mountains between 1946 and the present has been reconstructed from ground and aerial insect survey reports (Fig. II-7). This 44 year period shows 4 major tussock moth outbreaks. Minor fluctuations of tussock moth populations too small to result in detectable defoliation have likely occurred during interims between outbreaks. Populations of tussock moth increase and peak on the average of every 9 years, though cycles of infestation increase and collapse are variable (Shepherd et al. 1988).

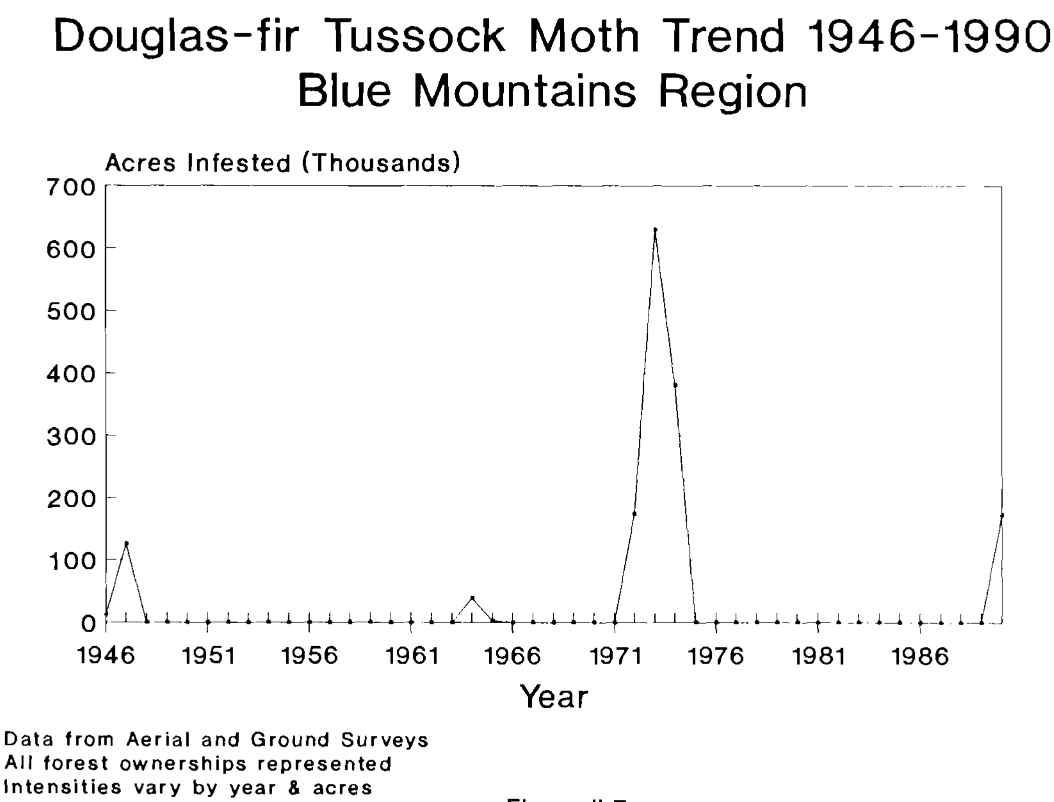

Figure II-7

Douglas-fir tussock moth defoliation trend from 1946 thru 1990 on forest lands in the Blue Mountains. (Based upon ground and Aerial Insect Detection Survey data)

The first tussock moth infestation shown in Fig. II-7 was detected near Troy and Promise, Oregon, in August 1946 on 10,000 to 12,000 acres of grand fir/Douglas-fir forest (Wickman et al. 1973). Local residents of the area noted that defoliation from tussock moth started in some locations in 1945. W. J. Buckhorn conducted a thorough aerial survey to map the defoliation in March 1947, and found that the infestation covered 56,065 acres west and north of Troy on private and Umatilla National Forest lands (Wickman et al. 1973). In June of 1947 three infestation centers of 1,500, 800, and 200 acres were reported on private land outside the Wallowa National Forest boundary near Promise, Oregon. In June and July of 1947, portions of both infestations were treated with an insecticide, and by 1948, natural control factors (nucleopolyhedrosis virus, and parasites, especially tachinid flies) had brought the remainder of the surviving infestation under control (Buckhorn 1948; Wickman et al. 1973). Two small areas totaling 1,120 acres of tussock moth defoliation on the southwestern part of the Malheur National Forest were mapped from the air in 1947. One area comprising 640 acres was south of Gold Hill. The other area (480 acres) was near the head of Sawtooth Creek. These small infestations resulted in very little damage. No further tussock moth-caused defoliation was reported anywhere in the Blue Mountains between 1948 and 1963.

In 1963, tussock moth defoliation was reported on 15 acres in mixed and pure stands of Douglas-fir and white fir on Antelope Mountain, on the Malheur National Forest (Wickman et al. 1973). Defoliation increased to 38,960 acres in 1964, and ground surveys for eggs in the fall of that year increased the total infested acreage on the Malheur, along with smaller infested area on the adjacent Ochoco National Forest, to 56,000 acres (Wickman et al. 1973). The infestation was treated with insecticides in June and July of 1965 which brought about an abrupt termination of larval feeding. It was also clear from monitoring that the outbreak was simultaneously declining because of disease, causing it to collapse completely by fall (Wickman et al. 1973).

Another infestation was discovered on the Malheur National Forest in 1965. This infestation was outside the area treated that year and comprised an area of 2,790 acres. It collapsed by the end of the summer without any control action being taken against it.

During ground surveys throughout eastern Oregon in 1970, tussock moth larvae were observed, but caused no visible damage to host trees. Tussock moth populations continued to remain at suboutbreak levels in the Blue Mountains during 1971, but in 1972, populations on the Umatilla and Wallowa-Whitman National Forests exploded to epidemic proportions, with visible defoliation extending over 173,600 acres. The outbreak stretched for 75 miles from La Grande, Oregon into southeast Washington. When the outbreak reached a peak in the Blue Mountains, 629,500 acres of Umatilla and Wallowa-Whitman National Forest land, and adjoining state and private lands were defoliated during the 1973 season. The acres defoliated in 1974 included 114,670 acres on the Umatilla National Forest, 132,147 acres on the Wallowa-Whitman National forest, and 134,400 acres of adjoining state and private lands. Thousands of acres of the outbreak were treated with insecticides, but much of the outbreak collapsed naturally without treatment, primarily due to nucleopolyhedrosis and other natural enemies and factors, including starvation.

Tussock moth populations remained low during succeeding years. In 1980, 20 acres of defoliation were reported (Pettinger 1985), apparently on Bureau of Land Management lands within the Blue Mountains, but an outbreak did not develop. Also, defoliation by tussock moths was noted in some areas north of La Grande during 1983, but populations had collapsed by 1984. And tussock moth populations continued to remain low until about 1989 when suboutbreak populations were discovered on the Pine Ranger District of the Wallowa-Whitman National Forest (Scott and Mason 1989).

Stand Conditions

The Douglas-fir tussock moth occupies many different site and stand conditions over its geographic range. It is not unusual for very low-density tussock moth populations to exist continuously in sites and stands containing host tree species, and never attain outbreak level. Tussock moth adult males, for example, have been captured in pheromone traps on the west side of the Cascade Mountain Range, where they never reach outbreak densities (Daterman 1978; Livingston and Daterman 1977). Tussock moth outbreaks are much more common at the warm and dry edge of the distribution of its major host species (Mason and Wickman 1988).

Habitat types that are characterized as forest/grassland ecotones, which are marginally productive for growth of firs tend to harbor the most severe infestations of tussock moth (Mason and Wickman 1988). These are typically poor productivity sites where tree competition for moisture and nutrients may be great. These sites are characterized by high density, mature, and overmature multistoried stands located on upper slopes, ridgetops, and shallow soils (Mason 1981; Stoszek and Mika 1978; Stoszek et al. 1981; Williams et al. 1979). Canopy layering of host species and overstocking promote tussock moth-induced damage by providing an abundance of landing sites on high-quality food, and habitat for young wind-dispersed larvae. Such conditions also insure survival by minimizing losses through non-target settling, predation, desiccation, and other factors.

These sites were predominately ponderosa pine sites in the past, but shade-tolerant fir species have encroached on the sites and become established due to fire suppression, selective harvesting of pine, and livestock grazing (Wickman 1978a; Williams et al. 1980).

From the foregoing information and other research results, we can construct a "generalized" list of site and stand conditions which run an increased risk of tussock moth defoliation:

- Stands located on the upper slopes are more commonly defoliated than stands on the lower slopes.
- Stands exposed to intense solar radiation on steep, south-facing slopes are more susceptible than those growing on less exposed sites.
- Trees growing on deep soils of volcanic ash seem to be less susceptible to defoliation.
- Tussock moth hazard seems to be related to stand density, and during periods of drought, increased stress from overstocking and low moisture may make stands more susceptible or vulnerable to damage.
- Stands with multi-storied structures are at higher risk than single-storied stands.
- Species composition affects stand susceptibility. Susceptibility increases with increasing proportions of true fir and Douglas-fir in the stand, and in later stages of the outbreak, Douglas-fir is much more severely defoliated in the Blue Mountains than grand fir in the same stands. Host preference and defoliation differences apparently vary by different geographic areas.
- Risk of defoliation also increases with age. Stands composed of trees less than 50 years old are at low risk, regardless of species composition, stand structure, or stand density.

Occurrence

During the tussock moth outbreak of the 1970's, the U.S. Department of Agriculture initiated the Combined Forest Pest Research and Development Program, an interagency effort that concentrated on the Douglas-fir tussock moth in the West, as well as on other forest pests in the South and Northeast. Behavioral chemicals research on tussock moth led to the development of a system of using traps baited with a synthetic version of the female moth's sex attractant or pheromone, for surveying forests for tussock moth (Daterman et al. 1979). The system provided managers for the first time with an "early warning" of tussock moth outbreaks. Adult male tussock moths are attracted to the pheromone bait and become "stuck" on the sticky inner surfaces of the cardboard trap containing the bait. Average trap captures that exceed 40 adult males indicate the potential for visible defoliation within the next two summer seasons, and point out the need for additional followup larval sampling (Mason 1979). This early warning system has been used annually in the Blue Mountains to monitor tussock moth population trends since 1980.

Tussock moth trap captures increased in certain locations on the Malheur and Wallowa-Whitman between 1986-1988 (Scott 1989). Followup larval sampling conducted in late spring and summer of 1989 found several locations with suboutbreak levels of tussock moth (Scott and Mason 1989). Of the area that was sampled, 10 percent was predicted to have outbreak levels of tussock moth in 1990, leading to the conclusion that an outbreak would be most likely to occur in 1991. Early and late larval tussock moth sampling was repeated in the same areas during 1990 and the sampled areas were found to contain some sites with outbreak levels of tussock moth (Scott, 1990 unpublished data). In the areas with highest tussock moth densities, inspection from the ground revealed some defoliation in the top-third of the crowns of some trees that could be attributed to tussock moth activity. However, aerial insect detection survey flights could not distinguish tussock moth defoliation from the wide-spread defoliation of western spruce budworm occurring simultaneously in the same areas. In any case, it was clear from the increase in larval densities that at least part of the Blue Mountains was heading into another tussock moth outbreak.

An extensive cocoon survey was conducted throughout the Pine Ranger District and adjacent areas of the La Grande and Wallowa Valley Ranger Districts, and the Hells Canyon National Recreation Area, to delineate the infestation. Cocoon densities, predicted to give rise to early larval populations in 1991 ranging from very low to outbreak, were found throughout the 172,800 acres of the area sampled (Scott, 1990 unpublished data). An environmental analysis is currently underway to determine tussock moth treatment needs.

Analyses of historical data on tussock moth outbreaks in the Blue Mountains and elsewhere (Clendenen et al. 1978; Shepherd et al. 1988) have shown that a major peak in tussock moth activity has occurred every 8-9 years. The regularity of fluctuations of tussock moth numbers around a mean population density in a systematic, rather than random, manner have encouraged the use of the term "cycles" to refer to these fluctuations (Mason and Wickman 1988). Long-term sampling of tussock moth in the Blue Mountains indicates that tussock moth densities oscillate with variable amplitude and produce only occasional outbreaks (Mason and Wickman 1988). Outbreaks of tussock moth often recur over large areas at the same time but will not necessarily infest the same stands from cycle to cycle (Balch 1932; Sugden 1957). The previous discussion on history and occurrence of tussock moth, and the trend of tussock moth in the Blue Mountains, underscores these facts.

Suppression

The first suppression operation against Douglas-fir tussock moth in the Blue Mountains was carried out on 14,000 acres of heavily infested merchantable timber on the Umatilla National Forest during the period between June 24 and July 1, 1947. DDT in fuel oil applied at the rate of one pound in one gallon per acre was applied to the infestation near Troy, Oregon, as a phase of the North Idaho tussock moth control project. The treatment resulted in nearly 100 percent control of tussock moth in the area treated. Some areas which experienced especially heavy defoliation in 1946, were too far weakened for the treatment to keep trees from dying. Mortality was supplemented by the Douglas-fir beetle which killed many of the weakened trees that might otherwise have recovered (Buckhorn 1948).

On July 15, 1947, the U.S. Forest Service and the State Forester's office conducted a joint suppression project on 320 of the most heavily infested portions of a 1,500 acre area near Promise, Oregon, on private land just outside the Wallowa National Forest boundary. DDT was applied at the rate of one pound in one gallon of fuel oil and xylene per acre, however, no appreciable reduction of the tussock moth population was obtained. Although it is not known with certainty, it was believed that the large larvae treated in this case were more resistant to DDT than were small larvae (Buckhorn 1948).

Suppression of Douglas-fir tussock moth populations with DDT was conducted again in the Blue Mountains during the 1963-65 outbreak. The project on the Malheur National Forest was conducted on four treatment units located between Burns, Oregon and John Day, Oregon. The acreages treated by unit are as follows: Antelope Mountain Unit - 23,000 acres; Gold Hill Unit - 11,655 acres; King Mountain Unit - 27,334 acres; and Vance Creek Unit - 661 acres. An additional 3,295 acres were treated on the Ochoco National Forest (Perkins and Dolph 1967). Insect mortality checks made ten days after spraying indicated that insect kill exceeded 98 percent. In addition, a pilot control study to evaluate the chemical insecticides Dursban and Zectran against the tussock moth was conducted in conjunction with the suppression project (Wickman et al. 1973).

In 1972, U.S. Environmental Protection Agency canceled the registration of DDT for forest insect control and most other uses. During the 1970's tussock moth outbreak, a flurry of activity to pilot test and field test both chemical and biological insecticides against the tussock moth to find a replacement for DDT, resulted in the registration with the Environmental Protection Agency (EPA) of several insecticides as potential control agents, including: *Bacillus thuringiensis*, TM BioControl-1 (a product containing the nucleopolyhedrosis virus of the Douglas-fir tussock moth), SEVIN 4 Oil (carbaryl), Orthene (acephate), and Dimilin (diflubenzuron) (USDA Forest Service 1978). Most of these projects were conducted on relatively small acreage at locations in Washington, Montana, Idaho, British Columbia, and New Mexico, as well as in Oregon.

Before these products could be registered, biological evaluations for tussock moth in 1972 indicated that, unless controlled, the outbreak might spread over as much as 434,000 acres by 1973 (Mounts 1976). The planning team formed to draft an environmental impact statement which considered several alternatives including: Aerial spraying with DDT, accelerated timber salvage with no direct control action, direct control with chemicals other than DDT, direct control with biological agents, and control via cultural practices. Because of lack of registered insecticides--chemical or biological--and the fact that other methods could not be applied before serious loss would occur, treatment with DDT was proposed (Mounts 1976). An emergency use request was made to the EPA, but the request was denied on the basis that the EPA felt the adverse environmental effects of using DDT might be more detrimental than predicted losses from tussock moth.

With the request denied, the Forest Service began plans to conduct large-scale tests with other chemicals. During June and July of 1973, a 70,000 acre test of Zectran was successfully conducted on forest lands in the Blue Mountains of northeast Oregon and southeast Washington, including about 32,000 acres of Umatilla National Forest and some private lands of the Walla Walla city watershed (Mounts 1976). Other smaller chemical tests conducted simultaneously with the Zectran test proved largely to be inconclusive (Mounts et al. 1973).

By the end of 1973, the tussock moth had caused enormous damage and loss to primary hosts in Oregon, Washington, and Idaho. The epidemic had damaged approximately 800,000 acres of standing timber; tree mortality was extensive on 88,000 acres and moderate damage was sustained on another 292,000 acres (USDA Forest Service 1981). Timber volume salvaged was estimated at approximately 560 million board feet (Mounts 1976), but these figures were apparently not based on a precise inventory and may be inaccurate. An egg mass survey in the fall of 1973 indicated another 649,000 acres of forest would be affected in 1974 (USDA Forest Service 1981). Again, DDT was recommended for treatment of tussock moth in 1974, and again, the EPA was petitioned for approval to use DDT.

After many public hearings, and extensive testimony, on February 26, 1974, EPA Administrator, Russell Train, granted the Forest Service an emergency exemption to use DDT, but imposed several restrictions; among which, he required that the Forest Service conduct comprehensive research on DDT alternatives (Mounts 1976). During June and July of 1974, 427,000 acres in Oregon, Washington, and Idaho were treated with DDT. The project included the treatment of 17,174 acres on the Pomeroy Unit (Umatilla National Forest); 88,417 acres on the Wallowa Unit (Wallowa-Whitman and Umatilla National Forests); 33,710 acres on the Halfway Unit (Wallowa-Whitman National Forest); and 38,051 acres on the La Grande Unit (Umatilla and Wallowa-Whitman National Forests). This was the last treatment for tussock moth outbreaks in the Blue Mountains.

Though highly controversial, the use of DDT against tussock moth outbreaks was claimed by some to be effective in suppressing populations and fulfilled the short-term objective of preventing excessive tree mortality. These claims are debatable, however, because the population was declining anyway, and many believed the outbreak would have collapsed without intervention. Further treatment may have impeded the ecological role of the tussock moth in reversing the trend of stand succession towards climax. In some treated stands, direct control precluded tussock moth from reducing concentrations of host species to levels that would positively influence competition among trees, stand composition, and structure which otherwise could develop into high-risk conditions in the future (Smith 1977; Stoszek 1978). Stoszek (1978) further suggests that unless followed by harvest or thinning, repeated application of direct controls further magnifies the problem of increased competition in an overburdened site-host tree system. Hence, the effects of direct suppression of tussock moth outbreaks are short-lived, treat only the symptoms and not the cause, and may postpone, rather than reduce, the probability of future outbreaks.

Effects

Douglas-fir tussock moth may be viewed as having both positive and negative affects on the forest ecosystem, as well as on the resources and benefits derived from the forest. Obviously, from an economic point of view, tussock moth outbreaks can have serious short-term and long-term effects on timber production (Mason and Wickman 1988). For example, defoliation by tussock moth tends to be patchy in intensity and more than one-half of the total tree mortality from tussock moth is concentrated in those patches, which make up a relatively small proportion of the outbreak area (Mason and Wickman 1988). However, the cumulative volume contained in these patches when added to the scattered mortality, could seriously affect the volume of crop trees harvested at the end of the current rotation. Furthermore, aside from immediate timber volume loss from tussock moth-caused mortality, many areas are left understocked or non-stocked, especially in the patches of mortality, at least for the short-term. Some inaccessible areas may not be salvaged for various reasons and may remain at or below minimum stocking levels for some period following the outbreak, while other areas may be restocked following salvage operations. Natural regeneration increases over many tussock moth damaged areas following the outbreak, and within the first decade of the postoutbreak period, moderate stocking of new trees will become established; although a portion of the area may remain understocked if the standard is based on a 60-percent stocking criterion (Wickman et al. 1986).

Research studies have shown that tussock moth outbreaks reduce the grand fir components of stands and encourage substantial increases in ponderosa pine over preoutbreak levels (Wickman et al. 1986). This research evidence also found changes in species dominance in the postoutbreak regeneration. Non-host Engelmann spruce, western larch, and ponderosa pine (in that order) were found to be the tallest and fastest growing species during the postoutbreak period. It seems that tussock moth outbreaks may in some cases benefit sites by encouraging establishment of faster growing seral species within openings created by tree mortality.

It is well established (Mason and Wickman 1984; Mason and Wickman 1988; Wickman 1978b) that the amount of damage to Douglas-fir and grand fir trees and stands is related to the degree of defoliation by tussock moth. Moreover, Douglas-fir in the Blue Mountains tends to suffer more damage than grand fir. During different stages of larval development, tussock moth can feed on both the current year's new foliage and the older needles. High-density populations can completely defoliate trees in a single season. Many trees suffering this degree of defoliation die, but others partially refoliate, sometimes during the same season or in the following spring, and apparently have enough starch reserves to survive. Occasionally, these trees that survive defoliation are further weakened and killed by drought or bark beetles (Berryman and Wright 1978; Mason and Wickman 1984; Mason and Wickman 1988). Generally, 90% of the trees die that have been defoliated 90% or more by tussock moth. Whereas, trees that lose 50-75% of their foliage rarely die from defoliation alone, but are often killed by bark beetles (Wickman 1978c; Wright et al. 1984). In essence, the highest direct mortality occurs in small understory trees. Larger trees are usually killed by a combination of defoliation and bark beetle attack.

Top-kill is also a common form of damage to host trees during tussock moth outbreaks, and usually occurs when the top 40% of the crown is defoliated. Top-kill can affect tree form and can result in some--though negligible--losses from decay. Although the long-term impact of top-kill in large trees appears to be negligible (Wickman 1978b), smaller trees with top-kill apparently do not develop heart rot and become unmerchantable by the time they are ready to be harvested (Aho et al. 1979; Wickman and Scharpf 1972).

Radial and height growth are also impacted by tussock moth defoliation. During and immediately following an outbreak, tree growth may be sharply reduced. However, this growth reduction is followed by rapid recovery. Growth recovery in stands studied in the Blue Mountains was found to begin the year after defoliation ceased, and by the fifth year, radial increment had returned to pre-outbreak levels (Wickman et al. 1980). Some studies even suggest that postoutbreak growth may significantly exceed preoutbreak growth. Radial growth rates of host trees 10 years after the outbreak were found to average higher than those just before the outbreak for most classes of defoliation (Wickman 1986). Increased nutrient cycling, especially nitrogen, in the form of insect Frass (excrement) following defoliation by tussock moth, may provide short-term increased growth of defoliated surviving trees and non-host pines which exceeds that of nondefoliated trees (Wickman 1980; Wickman 1988). The enhanced tree growth is apparently the result of increased nutrient cycling and the thinning effect of tree mortality. This suggests that some outbreaks may have positive effects on long-term stand productivity.

Loss of regeneration and cone crop production, especially in true fir species, are also a result of tussock moth outbreaks. Seedlings and saplings, as well as mature trees, are attacked by tussock moth causing losses to all age classes. More severe damage tends to occur in uneven-aged, multi-storied stands, as opposed to even-aged, single-storied stands.

Other impacts from tussock moth defoliation may be positive or negative. They include increased fire hazard; insignificant changes in total water yields (Studies on the 1972-1974 tussock moth outbreak suggested that tussock moth had no significant effect on water run-off, peak discharges, or low flows. Furthermore, water quality was unaffected.); changes in the balance between cover and foraging areas within habitat of big game; increased forage; creation of snags for snag-dependant wildlife; and diminished visual and recreational values (some studies suggest that tussock moth outbreaks do not have a significant effect on recreational land use, and in fact may increase use due to curiosity). Certain individuals who are sensitive to the barbed, urticating hairs of the tussock moth may find hiking through (or camping in) the woods discomforting during, and for some period of time following, a tussock moth outbreak due to the presence of tussock moth hairs in the environment. These hairs can become imbedded in the skin and cause temporary irritation, producing a rash ("tussockosis") in sensitive individuals who have had a history of general allergy (Perlman et al. 1976).

Hazard Rating

Systems to rate the risk of hazard to sites or stands with respect to defoliation by Douglas-fir tussock moth were developed during the 1970's outbreak. Two methods have been designed to predict potential tussock moth damage in spatial and temporal terms: One rates stands on grand fir and western redcedar habitat types of northern Idaho (Stoszek et al. 1984; Stoszek et al. 1981; Mika et al. 1981); the other rates stands composed of Douglas-fir and/or grand fir, in pure stands or in mixed composition with other overstory species (Heller and Sader 1980; Mika et al. 1981).

The second method was developed from data collected in the Blue Mountains, and probably best estimates the tussock moth defoliation hazard of sites in the Blue Mountains. It uses variables which can be measured on existing aerial photography to run through a regression equation to predict the probability of defoliation by tussock moth. The first method was developed through regression analysis of ground-based inventory data collected on defoliation intensity and site-stand characteristics. But, because both methods related similar physiographic and stand variables with high probability of tussock moth defoliation, they both may be applicable in the Blue Mountains.

Models

Computer models have been developed to simulate the population dynamics of Douglas-fir tussock moth in an outbreak (The DFTM Outbreak Model; Colbert et al. 1979), and stand development in forest stands affected by the Douglas-fir tussock moth (Combined Stand Prognosis and Douglas-fir Tussock Moth Outbreak Model; Monserud and Crookston 1982). A combined model of these two also exists which can be used to assess the likely consequences of both silvicultural treatments and tussock moth control activities for stands in the Northern Rocky Mountains (northern Idaho, western Montana, eastern Washington, northeastern Oregon), using existing forest inventories. Because it displays the projected results of alternative strategies for the management of forests affected by tussock moth, it can also be used as a tool for long-range timber management planning (Monserud and Crookston 1982).

To illustrate the use of tussock moth models in an economic analysis of Douglas-fir tussock moth control, the Malheur National Forest in Oregon and the Clearwater National Forest in Idaho conducted an analysis using the Combined Stand Prognosis/Douglas-fir Tussock Moth Outbreak Model and the FORPLAN Linear Programing Model to determine the economic efficiency of several strategies for dealing with an outbreak (Bousfield et al. 1984). These analyses evaluated the following scenarios: (1) No outbreak over 150 years; (2) no control of simulated outbreaks; (3) peak phase control, or control in the second year of an outbreak; and (4) decline phase control, or control in the third year of an outbreak.

The results of the analysis suggested that over a 150-year period the tussock moth threatens forest productivity under a variety of circumstances and that control is an economically efficient forest management practice. The results also suggested that tussock moth damage can be reduced more efficiently with a combination of control and intensive silvicultural treatments, such as multiple thinnings in both existing and regenerated stands, than with either tactic alone. Hence, the analysis using these models reinforces the concept of integrated forest pest management for tussock moth.

Management

Management for Douglas-fir tussock moth involves several phases that are linked in an integrated pest management approach. The first step is to hazard rate stands for susceptibility to tussock moth damage. Stands with a high proportion of grand fir or Douglas-fir trees, older than 50 years, with a high ratio of total biomass to site productivity, growing on sites located on ridgetops and upper slopes, and having shallow volcanic ash layer, are at high risk for attack by Douglas-fir tussock moth. Stands can be hazard rated using aerial photos (Heller and Sader 1980).

The next step is to monitor tussock moth populations by using pheromone traps in those areas identified as moderate or high hazard and areas where outbreaks have historically occurred. Presently, all ranger districts in the Blue Mountains are annually proceeding in this task using pheromone traps supplied by Forest Pest Management. The traps are placed in susceptible true fir/Douglas-fir stands in July and collected in October-November. Catches of 40 or more male tussock moth adults indicate a potential outbreak and activate intensive ground surveys by entomologists and district staff (Mason 1979).

In those stands identified as high hazard, work should commence to reduce hazard from tussock moth in the following manner. Forest management practices applied to high hazard stands should be designed to enhance or at least conserve soil moisture, soil organic matter, decomposition, and nutrient cycling and retention processes. Conversion of sites to seral non-host species is the most effective prescription for reducing the risk of tussock moth outbreaks (Mason and Wickman 1988). Where it is necessary or desirable to maintain some host species in the stand, provide a good mix of less pest-susceptible seral species and reduce severely the amount of true firs contained in any stands. Favor drought-tolerant species, reduce intertree competition by stocking control through thinnings or harvests, and shift to even-age management to create a uniform canopy at one level. On drier low- and mid-elevation sites, especially those on south-facing slopes and on ridgetops, favor ponderosa pines or other species that are best adapted to the conditions of the site. Do not stress susceptible host types by compacting, displacing, or eroding soil or injuring trees. Although no single prescription will be applicable to all site and stand conditions, a guiding principle should be to conserve and, where possible, enhance the primary natural controls that operate in limiting tussock moth populations, thereby creating conditions in which rates of population increase are naturally kept to a minimum (Mason and Wickman 1984).

Another step is to simulate tussock moth outbreaks and stand growth using the combined stand prognosis/Douglas-fir tussock moth outbreak model (Monserud and Crookston 1982). The consequences of tussock moth outbreak can be simulated using these models and treatment strategies can be altered and compared to measure their consequences and aid in making management decisions. Outbreaks can be simulated for a wide variety of stand conditions.

When direct suppression of tussock moth outbreaks becomes necessary and is selected as the preferred treatment strategy, utilize the effective and registered insecticides (TM BioControl-1, *B.t.*, Dimilin, Orthene, or SEVIN 4 Oil), following a thorough analysis of all factors relating to selection of the most appropriate control.

Lastly, use salvage and sanitation/salvage cuttings to remove severely defoliated and susceptible trees. Trees defoliated 90% or more by Douglas-fir tussock moth will probably die. These trees should be promptly salvaged to avoid buildups of bark beetles, woodborers, and wood degrading fungi, and also to recover merchantable volume and avoid losses from weathering or drying. Defoliated trees should be salvaged within 12 to 18 months after defoliation, depending on when bark beetles first attack the defoliated tree. However, some tussock moth-caused mortality creates snags and downed material usable as wildlife habitat, and a certain amount of them should probably be left for that reason. The precise amount to be left unsalvaged will need to be determined based on wildlife requirements, the potential for bark beetle buildup, and regulations and management policy.

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Douglas-fir Beetle (Dendroctonus pseudotsugae Hopkins)

Hosts and Community

The Douglas-fir beetle is the most destructive bark beetle pest of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, in the Blue Mountains. Douglas-fir is the principal host of the Douglas-fir beetle, although rarely, other conifer species have been reported to be attacked, including western larch, *Larix occidentalis* Nutt.; tamarack, *L. laricina* (Du Roi) K. Koch; and western hemlock, *Tsuga heterophylla* (Raf.) Sarg. Western larch (usually weakened by dwarf mistletoe or other factors) may occasionally be attacked when present in Douglas-fir stands undergoing attack by Douglas-fir beetle, but the beetle will not produce broods in living larch (Furniss and Orr 1978; Furniss et al. 1981). The Douglas-fir beetle is found only in Douglas-fir and in fallen or injured larch (Bedard 1950), and the broods emerge from larch at rates equal to broods found in Douglas-fir (Furniss et al. 1981).

Douglas-fir beetle occurs in any vegetation community containing susceptible hosts, including subalpine fir/lodgepole pine (CE/CL), grand fir (CW), and Douglas-fir (CD). The most likely communities in which to find the Douglas-fir beetle, of course, are those containing the greatest abundance of primary host, Douglas-fir. Hence, stands in the CD community and the CW are the vegetation series where Douglas-fir beetle are most often found.

Biology

The Douglas-fir beetle produces one generation per year and mainly overwinter as callow or teneral adults (a condition of the insect after transforming from pupa to adult, and shortly before emergence from the host, in which the adult has not fully hardened and tanned to its mature color). Broods may overwinter as larvae also. Adult beetles that overwintered as adults, or as late-instar larvae that transformed to adults in early spring, emerge from the inner bark and take flight in search of new hosts as air temperature warms above 65° F (Furniss et al. 1981).

Female beetles attack trees first, emitting an odor upon entering the bark that attracts other flying beetles to the tree. Attractiveness of the pheromone is synergized by volatiles contained in the resin of host trees (Furniss and Schmitz 1971). These pheromones attract beetles of both sexes so as to concentrate their numbers in order to help in overcoming the natural resistance of trees, and in locating mates. These aggregative pheromones cause beetles to attack groups of trees (Furniss et al. 1981). After mating has taken place, beetles produce another odor, an antiaggregant, that disrupts attraction. The function of this compound is to reduce intraspecific competition by terminating attraction after a generally sufficient attack density has been achieved (Furniss et al. 1982; Rudinsky and Ryker 1976).

At the innerbark, near the sapwood, beetles construct an elongated gallery within which the female beetle lays eggs in alternating groups along its sides. The beetles carry with them spores of a blue-stain fungus, *Ophiostoma pseudotsugae* (Rumb.) von Arx (= *Ceratostomella pseudotsugae* Rumbold), which germinate and develop in the conducting tissues of the tree, blocking the transpiration stream. The fungus kills the tree in concert with the girdling activities of the brood, a process that is usually completed within a few weeks of inoculation; though normally, the tree will not fade until the following season. In fact, the fungus itself can girdle and kill a tree, even when the Douglas-fir beetle fails to develop successful broods (Bedard 1950).

The eggs hatch into white, legless grubs or larvae with brown heads. When mature, the larvae transform into white pupae, and finally emerge as adults. The life cycle of the Douglas-fir beetle can sometimes become confusing because they have the ability to produce two broods during each season. Callow adults which overwintered, emerge in the spring and attack whole trees, fresh slash, snow breakage, fire-kill, and windthrow in April or May. The first brood of the season is produced by these overwintering callow adults. Some adults that produced the first brood in the spring re-emerge and attack again during the summer (usually in late June and July) and produce a second brood, after which these parents die. The first brood, being more developmentally advanced, reach the end of the fall and spend the winter as callow adults, whereas, the less developed second brood overwinters in the larval stage. In the spring, the overwintering second brood resumes development and begins pupating in May, transforming to adults within about a week. Although beetles emerge to infest fresh host material from May to August, the main emergence takes place in the spring (Walters 1956). The summer attack by beetles is less intense and occurs over a longer period than the spring attack, and is therefore less critical with respect to the infestation of living trees (Walters 1956).

Douglas-fir beetles do not produce pitch masses at their points of attack on trees, unlike some of the other bark beetles of the genus *Dendroctonus*. Pitch is found only in those entrance holes from which the beetles have been "pitched out" (Walters 1956). The presence of clear resin exuding from entrance holes, usually on the upper portion of the bole indicate the upper limit of the infestation (Furniss and Orr 1978).

History

The outbreak history of Douglas-fir beetle in the Blue Mountains prior to 1949, when annual Aerial Insect Detection Surveys were begun, could not be determined at the time this manuscript was prepared. However, a nearly complete record of Douglas-fir beetle outbreaks from 1949 to 1990 was summarized from annual aerial survey records (Fig. II-8). It should be noted that the acreage depicted in the graph was infested at varying intensities by the Douglas-fir beetle; so not all acres were equally infested.

An insect survey report covering insect conditions in 1947 (Buckhorn 1948) makes mention of an active outbreak of the Douglas-fir beetle on the Wallowa National Forest, in the Chesnimnus drainage. There was a special significance to this outbreak of bark beetles because of the likelihood that the Douglas-fir beetles were invading trees that were already weakened by spruce budworm. During this time, the Blue Mountains was experiencing an outbreak of the western spruce budworm. A large area covering 127,000 acres on the Wallowa National Forest was reported to be defoliated during 1947. It was feared that as the defoliation intensified, the threat of bark beetle mortality would become more acute. The report did not mention the size of the area in which trees were being attacked by the Douglas-fir beetle.

Meanwhile, a Douglas-fir tussock moth outbreak on the Umatilla National Forest in 1947, caused 100 percent mortality on an estimated 500 to 600 acres, and weakened trees over much of the 10,000 to 12,000 acres of mixed-fir type involved in the infestation. The following year, Douglas-fir beetle populations attacked many of the trees that were seriously weakened by tussock moth during both 1947 and 1948. The Forest Service scheduled a salvage sale on about 1,000 acres to utilize the dead and threatened timber and to effect control over the insect populations through the removal of infested trees.

During the 1949 season, infestations of Douglas-fir beetle in the Blue Mountains covered some 184,100 acres. This outbreak was reported to be declining slowly from epidemic peak years on the Wallowa National Forest in 1947, and on the Umatilla National Forest in 1948 (following the tussock moth outbreak). At that time, entomologists found no indication that the Douglas-fir beetle had initiated large-scale attacks on trees weakened by spruce budworm defoliations.

Although no reports on Douglas-fir beetle could be found for the Blue Mountains during the years 1950 and 1951, it is interesting to note that the western parts of Oregon and Washington suffered severe wind damage during the winter of 1949 and 1950, which led to a build-up of Douglas-fir beetle in the windthrown and broken trees. A tremendous volume of green standing timber was attacked and killed during 1951 by the beetles that emerged from the wind-damaged trees. It is likely that some blowdown also occurred in The Blue Mountains, and possibly led to attacks by Douglas-fir beetle on these trees damaged by the windstorms as well as on those weakened by defoliators.

By 1952, the budworm outbreak in the Blue Mountains was in its 8th year, and the weakening of host trees had led to an epidemic of the Douglas-fir beetle. The bark beetle outbreak had developed on both sprayed and unsprayed areas in the Blue Mountains of Oregon and Washington, killing significant numbers of trees already weakened by budworm. In some drainages on the Umatilla National Forest, nearly all the Douglas-fir of saw timber size were killed by the Douglas-fir beetle. Although a report of Douglas-fir beetle conditions for 1951 could not be found, the bark beetle epidemic is recorded in the survey report for the 1952 season, which states that the outbreak first became an epidemic in 1951 in the Blue Mountains.

The Douglas-fir beetle epidemic continued in stands of the Blue Mountains during 1953, primarily in trees weakened by the cumulative years of budworm defoliation. Some reports indicated that the bark beetle outbreak was so severe in places that it was useless to control the budworm while the Douglas-fir beetle was in epidemic. One report for the Washington area of the Blue Mountains stated that "...tree killing by bark beetles so far outweighed the defoliation by the budworm that it was impossible to map the defoliated stands."

But by 1954, survey records show that the acreage on which Douglas-fir beetle was epidemic had dropped. Although the beetle was still killing considerable numbers of trees in the Blue Mountains. And within a few years, the Douglas-fir beetle outbreak in the Blue Mountains--the worst in this region in the past 40 years--declined to endemic levels.

The four other major peaks of Douglas-fir beetle epidemics in the Blue Mountains, dating from 1957 on (Fig. II-8), also coincide with past defoliator outbreaks. The peaks from 1957 to 1963, and from 1987 to 1990 coincide with budworm outbreaks. The peaks from 1963 to 1966, and from 1974 to 1980 coincide or follow Douglas-fir tussock moth outbreaks during or following those years. In addition, Hurricane Frieda struck Oregon and Washington on October 12, 1962, creating an enormous amount of blowdown and, therefore, habitat for bark beetles. Much of the windthrown Douglas-fir was attacked by Douglas-fir beetle, prompting rapid salvage efforts to avoid building up greater populations and associated tree killing when these broods emerged. The years 1976 and 1977 were drought years, and some of the losses of Douglas-fir due to Douglas-fir beetles' activities during this period may have been related to drought in addition to Douglas-fir tussock moth defoliation.

These bark beetle trends show very clearly the close association between the tree weakening by defoliators (and probably drought), and subsequent attack by bark beetles. They also show the rapid utilization of an abundant food source created by severe windstorms. These associations are some of the most predictable host susceptibility-bark beetle attack relationships in forest entomology. However, while we may understand the general conditions which make trees susceptible to insect attacks, there is a lot we do not know about defoliator/drought and Douglas-fir beetle dynamics in the dry interior stands of the Blue Mountains Forests. Yet predictive models and guidelines that would help determine when trees have been defoliated enough that they become susceptible to the beetle, or to what degree other factors might influence beetle attack and buildup to outbreak are almost totally lacking. Research in this area is sorely needed.

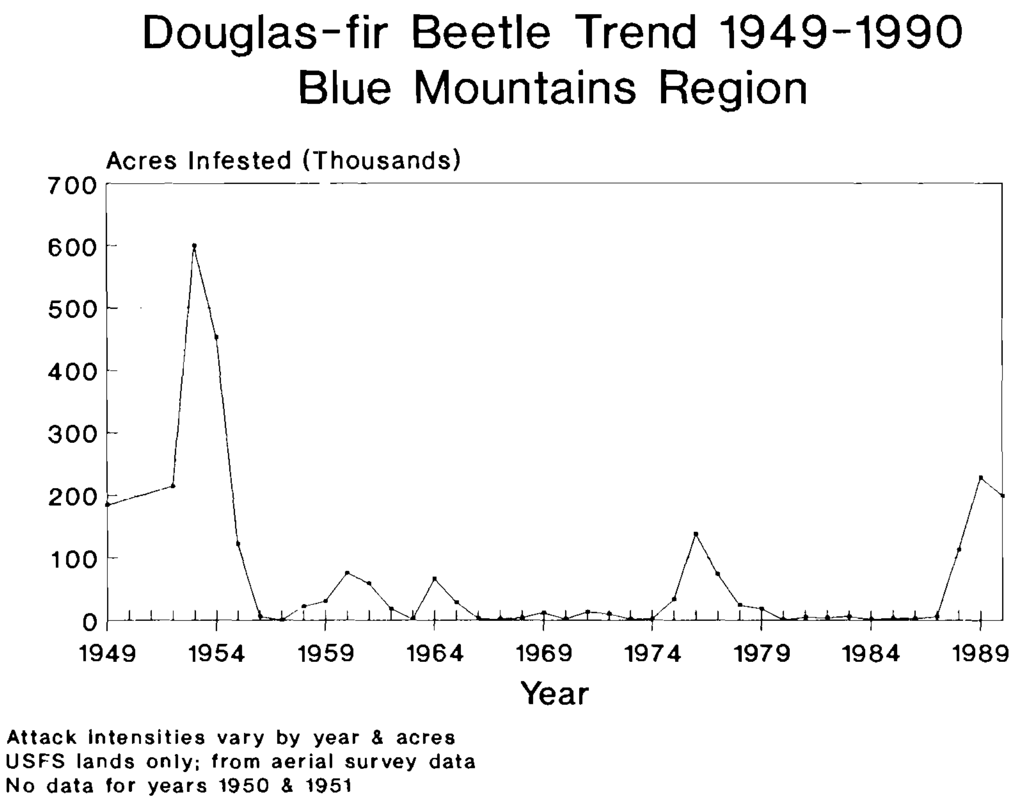


Figure II-8
Douglas-fir beetle infestation trend from 1949 thru 1990 on National Forest lands (Malheur, Umatilla, and Wallowa-Whitman) in the Blue Mountains. (Based upon Aerial Insect Detection Survey data)

Stand Conditions

Outbreaks of the Douglas-fir tussock moth in the Blue Mountains and the Interior West differ from those of the coastal areas. Outbreaks in the inland regions often last many years and may not decline until essentially all the trees of susceptible size (usually over 10 inches DBH) in the stand or drainage are killed (Wright and Lejeune 1967). In coastal areas, outbreaks are usually of short duration, lasting no more than 2 or 3 years. However, susceptible stands in both coastal areas and inland can be devastated by Douglas-fir beetle following stand disturbances (Furniss et al. 1979; Wright and Lejeune 1967). Outbreaks in coastal areas have usually followed a similar pattern: Populations typically build-up following major stand disturbances such as blowdown and fire-kill, spread to green trees, kill large volumes of timber, and then decline rapidly as more vigorous and resistant trees are attacked (Wright and Lejeune 1967). In the Interior, relationships involving outbreaks seem more diverse, and are probably stimulated by other predisposing factors in addition to windstorms and fire.

Douglas-fir beetle is normally considered a secondary pest, preferring to attack low vigor and recently dead trees, such as those that have been windthrown; struck by lightning; infected with root disease, dwarf mistletoe, or stem decay; or stressed by factors such as drought, defoliation, wildfire, snow breakage, and logging operations (the large debris left after logging is also preferred)(Bedard 1950; Coulson and Witter 1984; Fredericks and Jenkins 1988; Furniss and Carolin 1977; Lejeune et al. 1961). In addition, outbreaks of Douglas-fir beetle appear to be closely related to stand conditions such as overmaturity and overstocking, and to climatic conditions such as drought (Wright and Lejeune 1967).

Several factors are responsible for the susceptibility of a stand to attacks by Douglas-fir beetle. In their study of a Douglas-fir beetle outbreak in northern Idaho, Furniss et al. (1979) found that the proportion of Douglas-fir in a stand, and its density and age were positively correlated with susceptibility. Moreover, they found that any of these factors can influence damage, but high stand density can result in somewhat younger trees being attacked. For this outbreak on the North Fork of the Clearwater drainage, their observations showed that: (1) Attacked groups of Douglas-fir trees were typically on good sites in stands composed mainly of Douglas-fir growing more densely than normal; (2) age of attacked trees varied--some averaging only 90 years old--but, as a whole they were unusually young in relation to other Rocky Mountain infestations; (3) the rate of tree-killing declined in the fourth beetle generation; (4) the decline in the infestation was accompanied by cessation of major stand disturbances, smaller groups of infested trees, higher proportion of unsuccessfully attacked trees, and an average beetle population index of 1.1 in early fall; (5) little change was apparent in density of immature parasites and predators on bark samples between years, and several were scarce on samples throughout the study; and (6) tree susceptibility to beetle attack may be related to infection by root rots.

Furniss et al. (1981) also found that Douglas-fir beetle-induced mortality could be directly correlated with three factors that were universally present in stands undergoing a beetle outbreak: Stand density, stand age, and proportion of Douglas-fir. Furthermore, it was found that any one of those factors could limit mortality; an example is the fact that a dense stand of young Douglas-fir (less than 80 years) is not generally susceptible to being killed by Douglas-fir beetle. The authors also reported that they had never seen a Douglas-fir beetle outbreak in residual stands after any kind of commercial cutting. Stands in northern Idaho in which tree-killing by Douglas-fir beetle occurred, typically contained Douglas-fir as a major species component and were stocked at 80 to 124 percent of normal (241 to 361 $ft.^2$/acre) (Furniss et al. 1981). After examination of hundreds of Douglas-fir beetle-killed trees, Furniss et al. (1981) found that the average age exceeded 120 years, but that figure varied somewhat with locality and population pressure. These findings support Walters' (1956) statement regarding host age and susceptibility. Walters indicates that trees over 150 years old, especially those that are slow growing, are more susceptible than younger, more vigorous trees.

Over the past couple of years, a number of mixed conifer stands in the Blue Mountains, containing a large proportion of Douglas-fir, have been killed by the Douglas-fir beetle. Our observations indicate that in many cases these stands have similar characteristics: The stands are mature or overmature; overstocking is the rule (some stands have 160 percent of recommended stocking); the majority of stocking is in medium and large diameter trees (10-40 inch DBH); stands are "old-growth" in character (some were dedicated "old-growth" set-asides); stands included or were associated with riparian areas; stands have been defoliated by budworm for many years (generally, 6-8 years); most or all of understory true fir and Douglas-fir species had been killed by budworm; and subnormal precipitation, (resulting in drought) has caused additional stress on trees for 4 or 5 years.

These stands have incurred catastrophic levels of mortality through the combination of budworm, Douglas-fir beetle, and drought. Mortality has even increased to the point that these stands have lost their "old-growth" quality and characteristics as defined by the National Forests' Land and Resource Management Plans. For example, in one old-growth stand, we found that 89 percent of the Douglas-fir basal area had been killed by the Douglas-fir beetle.

While depredations from endemic populations of forest insects and diseases balance species diversity and contribute to site productivity by cycling nutrients, epidemic levels and catastrophic losses from these mortality agents are indications of an ecosystem in distress. The role of insects, when they build to outbreak levels and cause catastrophic mortality, is simply nature's attempt to stabilize and revitalize the system by altering nutrient levels, microclimate, species composition, stand age, stand structure, and stocking density.

Occurrence

Douglas-fir beetle populations in the Blue Mountains have occurred at relatively low levels for most of the past 10 years (Figs. II-9). Up until about 1988, Douglas-fir beetle attacked trees on only a few thousand acres, at most, on any one of the National forests in the Blue Mountains. Although the Malheur National Forest seemed to experience the least amount of Douglas-fir beetle activity from 1980 through 1987. During this period Douglas-fir beetles attacked trees on a total of only 240 acres there, based on aerial survey data (Fig. II-9).

Cumulative defoliation by western spruce budworm since 1980 (the start of the latest outbreak) in conjunction with drought stress over the past four or five seasons have weakened trees, increasing their susceptibility to Douglas-fir beetle on all three Blue Mountains National Forests. A rapid buildup of beetle populations in the weakened trees began on all three National Forests about 1987. Many of the trees that were attacked during the 1987 season probably had not faded by the time the aerial survey was conducted in late summer that year. However, the clear evidence of the infestation showed up during the survey conducted in 1988 (Figs. II-9). And though populations appear to have declined slightly on the Malheur National Forest (Fig. II-9), the outbreak continued to increase through 1990 on some of the Districts on the Umatilla and Wallowa-Whitman National Forests (Fig. II-9). The North Fork John Day Ranger District experienced the largest increases in area infested by Douglas-fir beetle due to the widespread and severe defoliation by the budworm. The La Grande Ranger District experienced a similar buildup of bark beetles in severely defoliated areas, and aggressive action to salvage the dead and remove green-infested trees over parts of the outbreak may have helped to lessen its impact and duration. Our experience has been that the buildup of beetle populations and most of the tree killing occurred over a three or four year period during this latest defoliator outbreak.

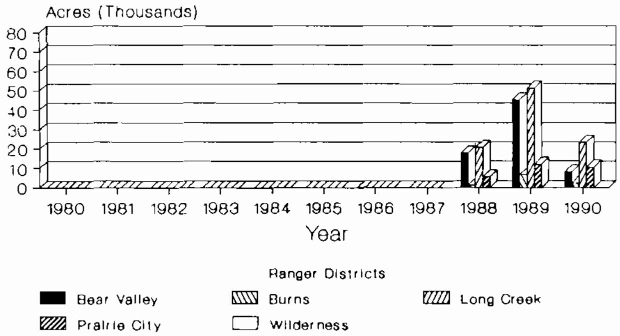
Another Douglas-fir beetle situation we have been monitoring closely is the buildup of populations associated with wildfires on areas of the Hells Canyon National Recreation Area, Eagle Cap Ranger District, and Wallowa Valley Ranger District. The major fires, dating from 1986, include the Joseph Canyon Fires (58,800 acres); Pumpkin Creek Fire (14,048 acres); Tepee Butte Fire (59,860 acres); Emmett Complex Fires (9,503 acres); Enterprise complex Fires (23,350 acres); and Summit Complex Fires (9,060 acres).

Douglas-fir was present in many of stands that were injured by the fire. This fire-injured host provided an abundance of habitat in which Douglas-fir beetle could breed. Bark beetle populations, resident in stands within proximity to the fires, were drawn to the injured host trees and began colonizing them, attacking the most severely injured trees first. As these broods developed and emerged as adults the following spring, more fire injured trees were attacked and succumbed to the beetle. Thus, the large number of fire-injured trees provided a food supply that allowed beetles to rapidly increase in numbers, and the increases in Douglas-fir beetle populations on the Hells Canyon National Recreation Area and Eagle Cap Ranger District from 1988 to 1990 (Fig. II-9), are the result of these recent fires.

Suppression

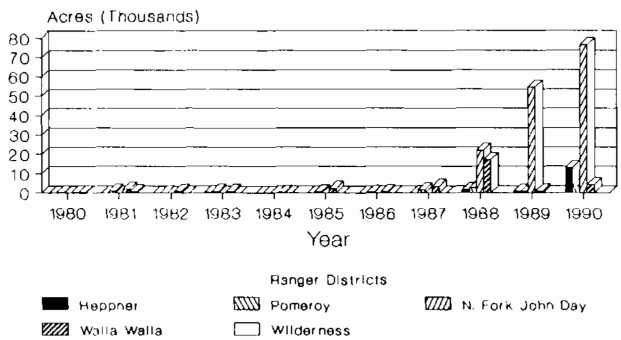
The principal means of controlling or suppressing Douglas-fir beetle outbreaks in the Blue Mountains has been through salvaging and sanitation cutting. The prompt salvage removal and clean-up of breeding material such as blowdown, fire-kill, and large logging slash, and logging practices such as reducing the height of the stumps can do much to reduce beetle populations (Wright and Lejeune 1967). These practices and others are still used today to reduce beetle populations and recover merchantable volume before deterioration occurs.

Douglas-fir Beetle Infested Acres
Malheur National Forest



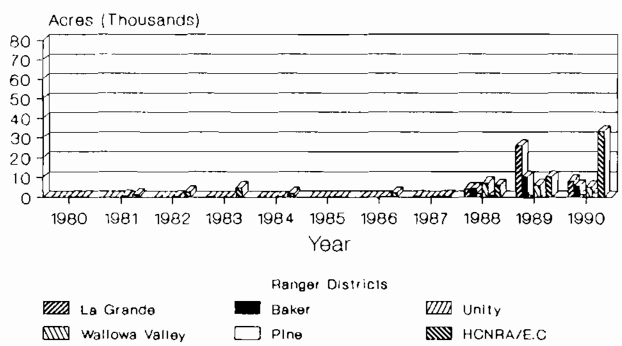
USFS lands only
Attack intensities vary by year & acres
Wilderness data incomplete

Douglas-fir Beetle Infested Acres
Umatilla National Forest



USFS lands only
Attack intensities vary by year & acres
Wilderness data incomplete

Douglas-fir Beetle Infested Acres
Wallowa-Whitman National Forest



USFS lands only
Attack intensities vary by year & acres
Eagle Cap Wilderness data incomplete

Figure II-9

Acres with visible Douglas-fir beetle-caused tree mortality on National Forests in the Blue Mountains from 1980 thru 1990. (Based upon Aerial Insect Detection Survey data)

Few methods of direct control have proved practicable in suppressing Douglas-fir beetle outbreaks (Wright and Lejeune 1967). According to Keen (1952), the usual method of direct control is to fell the tree and cut the infested bole into logs, which are then decked and burned. Some applications of chemicals such as orthodichlorobenzene, trichlorobenzene, dichloroethylether, or ethylene dibromide in either diesel oil or water emulsion have been used with success on a limited basis to control broods in thin-barked trees in Idaho (Wright and Lejeune 1967). Other chemical insecticides have also been used on limited basis, including Aldrin, lindane, heptachlor, Thiodan, and isodrin. However, use of these chemicals have long been abandoned as impractical or have been suspended from use by the U.S. Environmental Protection Agency.

Effects

When populations of Douglas-fir beetle, usually a secondary insect pest, are attracted to a susceptible food source--weakened, dying, or recently-killed Douglas-fir timber--in greater numbers than the host can accommodate, some beetles will attack and kill small, nearby groups of green trees. When their favored food supply has been exhausted, the brood that develops in this material may emerge the following spring and attack and kill patches of healthy, green Douglas-fir timber, thereby becoming a primary insect pest. In drainages where the natural resistance of host trees has been lowered by defoliation, fire injury, drought, disease, or some other factor, the generally weakened condition of the stand may allow populations of Douglas-fir beetles to easily overcome trees, become established, and increase their numbers to epidemic proportions, sometimes killing nearly every host tree in the drainage. This kind of episode could have devastating consequences in any area being managed for resource values, no matter what type.

Tree-killing by the Douglas-fir beetle is often greatest among stands of mature or overmature Douglas-fir. For this reason, we see in the Blue Mountains, among stands that have been ravaged by western spruce budworm, some of the most dramatic losses in old-growth Douglas-fir by the Douglas-fir beetle. All too often these stands are part-and-parcel of a riparian ecosystem, and catastrophic losses of the Douglas-fir component can significantly effect the entirety of such an ecosystem and more. Changes in light intensity, solar insolation on soils and watercourses, radiant energy, evaporation losses, soil stability, interception of precipitation, runoff, low- and peak-flow rates, wildlife habitats and travel routes, cover ratios, species diversity, size and age distribution of woody vegetation, stand structure and stocking density, fuels loading, and visual components, are all influenced by Douglas-fir beetle epidemics in riparian ecosystems.

Within larger drainages, these same impacts can be brought about by epidemic-related losses due to the Douglas-fir beetle. Results from our own old-growth stand evaluations in the Blue Mountains (Scott and Schmitt, unpublished, 1990) indicate that losses of the Douglas-fir component caused by the Douglas-fir beetle can exceed 89 percent of the basal area stocking (63 percent of the trees per acre), and 65 percent of the total stand basal area (36 percent of the trees per acre) in mixed-conifer stands primarily composed of Douglas-fir, ponderosa pine, and lodgepole pine. This is tantamount to a "species conversion," and is brought about by the Douglas-fir beetle operating in western spruce budworm-defoliated stands.

Oftentimes, because beetle-caused mortality occurs in widely-scattered patches, many of which are in remote, inaccessible locations, mortality groups may go unsalvaged. This "patchwork" of mortality creates openings which may benefit big game and domestic livestock through increasing forage production: But if they are very large, these openings may significantly reduce stocking levels and take valuable, productive sites out of timber production until regeneration can occur.

Hazard Rating

Very little has been done in the past to develop methods to hazard-rate stands for susceptibility to Douglas-fir beetle. Probably the greatest contribution in this regard is the work by Furniss et al. (1981). The authors undertook an holistic approach to mathematically define the probabilities of mortality, given various stand data. They studied 24 tree-related, stand-related, site, and physiographic variables to develop a probability function using the RISK computer program (Hamilton 1974; Hamilton and Edwards 1976). They then used it to compute a numerical value from 0 to 1--proportional to the degree of risk of mortality--for any combination of variables determined to be significant from prior evaluation with the computer program SCREEN (Hamilton and Wendt 1975). The result is that the modified function establishes correlation between independent variables and either the presence or absence of mortality. The procedure provides a convenient means of stratifying stands by their degree of risk of Douglas-fir beetle-induced mortality. Since many of the variables were developed from plots in north Idaho (Clearwater River drainage), and using habitat typing different from that used in the Blue Mountains, it is doubtful the procedure could be used with any degree of success in the Blue Mountains. The procedure appears to be sound, and if "adjusted" for Blue Mountains variables, it could prove to be a valuable tool in hazard-rating the susceptibility of stands to Douglas-fir beetle and then in prioritizing them for treatment. Additional work in Douglas-fir beetle hazard-rating methodology would be beneficial to Ranger Districts if a reliable method could be developed.

Models

Computer modeling of Douglas-fir beetle population dynamics and damage in the Blue Mountains is also sadly deficient. There are currently no models available, although the USDA-Forest Service Forest Pest Management, Methods Application Group (MAG) is presently working on a Douglas-fir beetle model as part of the multiple-pest modeling capability of the Integrated Forest Management System (INFORMS). The model will be a new extension to the stand growth and yield projection model, PROGNOSIS, and will be applicable anywhere in the Blue Mountains (Bov Eav, personal communication, 1990).

Another model--though not computer-aided--that is applicable to the Blue Mountains is that of Berryman and Wright (1978). Their model allows the estimation of expected maximum annual (cumulative) timber mortality, based on year of cessation of Douglas-fir tussock moth defoliation. It may be possible to adapt this model for use in determining timber mortality rates relative to degree of western spruce budworm defoliation. The original model was based on data for the Blue Mountains, obtained during the 1970's Douglas-fir tussock moth outbreak, so it should be widely applicable for the Blue Mountains.

Management

Silvicultural management of stands to promote vigorous growth, avoid overstocking and suppression, and maintain stand age below 150 years, is the best way of reducing beetle-caused losses of Douglas-fir. Stands should be managed to provide 67 percent of full stocking, and should not exceed the 75 percent level, in order to minimize suppression and suppression mortality (Seidel and Cochran 1981). Commercial thinning should be done in dense (small sawlog-size or larger) Douglas-fir or mixed conifer stands in the Blue Mountains in order to meet the defined stocking level objective; thinning should be mostly from below, with vigorous trees being left (Seidel and Cochran 1981). Where management direction for an area requires maintaining stands beyond normal rotation, other measures may need to be taken to prevent Douglas-fir beetle losses. Methods could include: Additional thinning from below, fertilization, use of antiaggragative pheromones (if these prove to be efficacious in this type of application), and early suppression of defoliator outbreaks.

Direct control is another aspect of Douglas-fir beetle management that may be applied where warranted. Methods to directly control the Douglas-fir beetle, while useful on a very limited basis, have not been satisfactorily demonstrated as practical for outbreaks larger than the very smallest ones. Once outbreaks of Douglas-fir beetle become widespread, it is difficult to significantly alter the course of an outbreak by any method. Wright et. al. (1984) found that populations of beetles that increased in numbers following defoliation of Douglas-fir tussock moth defoliation, rise substantially after stress from defoliation is removed, and continue to kill trees for two or three years before tree resistance improves and the beetles disperse from stands.

Some of the methods that have been effective (or show promise) include: The trap-tree method; baited trap-tree ("trap-cropping") using aggregation pheromones; and use of the antiaggregative pheromone, 3-methyl-2-cyclohexen-1-one (MCH), to prevent spread of beetles in windthrow and their subsequent attacks of standing green trees (Furniss 1959; Furniss et al. 1981; Lejeune et al. 1961). The first two methods require removal of infested trees prior to beetle flight in the spring. The third method is more preventative in nature than a direct suppression technique (Johnsey 1984). MCH can currently only be used under an experimental use permit, on a limited basis. However, the use of aggregation pheromones for trap-cropping does not require EPA registration.

The final means of managing Douglas-fir beetle populations is accomplished through salvage and sanitation in susceptible and damaged stands, and through application of appropriate harvesting techniques in conjunction with sound cleanup efforts afterwards. The following guidelines have been widely used for minimizing losses caused by the Douglas-fir beetle in the Blue Mountains and throughout the Pacific Northwest Region:

- **Salvage storm or fire damaged areas within 12 months of the event.**

  Douglas-fir beetles prefer to attack recently damaged trees. They will attack windthrown or severely damaged trees in the spring and produce a brood that emerges a year later. Damaged trees should be salvaged within 12 months to prevent beetles from attacking proximal healthy trees after they emerge. If an event creating dead and damaged Douglas-fir occurs during May, June, or July, the trees should be removed before the following April. Beetle-infested trees can be identified by red boring dust in bark crevices and crowns that begin to fade in late summer.

- **Do not leave large quantities of cull logs greater than 8 inches in diameter.**

  Douglas-fir bark beetles will infest fresh logging slash larger than 8 inches in diameter in the spring and early summer. If there is a large amount of slash, the beetles emerging the following spring could attack and kill nearby healthy trees. Dispose of cull logs within 12 months of when they are cut. If trees are cut during May, June, or July, the trees and large logging slash should be removed before the following April.

- **Salvage stands that have been killed by defoliation or that are beginning to be attacked by beetles.**

  Douglas-fir stands that have been severely defoliated may be attacked by Douglas-fir beetles, especially if the trees have been killed by defoliation. Dead trees and those with severe defoliation should be promptly salvaged to prevent development of Douglas-fir beetle outbreaks. If defoliated trees are not dead, wait to see if beetles begin to attack, and at the first sign of such an attack, salvage the most seriously defoliated trees.

- **Check beetle-infested trees for root rot.**

  Many of the patches of trees killed by Douglas-fir beetles have root rots that weakened the trees, making them attractive to the bark beetles. The beetle-infested trees should be salvaged and the stands treated for root diseases. Control of the root diseases will control the beetles, barring any other factors contributing to the susceptibility of the stand.

- **Do not leave large amounts of fresh larch cull logs in harvest areas.**

  Douglas-fir beetles can infest and produce broods in larch logs larger than 8 inches in diameter. Emerging broods can attack living Douglas-fir; they generally will not attack living larch. If large amounts of fresh larch cull logs are present they should be removed within 12 months of the time they are cut. Normally, larch cull logs will not be left for very long because of the high demand for larch firewood in the Blue Mountains.

- **Keep stump height as low as possible.**

  Douglas-fir beetles often attack and produce brood in high, large-diameter stumps. Stumps should be cut as low as possible and, if infested, treated (peel bark) to destroy the bark beetles in them (Lejeune et al. 1961).

- **Minimize damage to residual trees during logging operations.**

  Care must be taken that as little mechanical damage as possible occurs to the residual stand. This includes root damage such as that caused by road cuts (Lejeune et al. 1961).

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Mountain Pine Beetle (Dendroctonus ponderosae Hopkins)

Hosts and Community

The mountain pine beetle is considered the most destructive of all bark beetles occurring in the West (Furniss and Carolin 1977). This bark beetle attacks and kills three major host trees in the Blue Mountains: Lodgepole pine (*Pinus controta* Dougl.), ponderosa pine (*Pinus ponderosa* Laws.), and western white pine (*Pinus monticola* Dougl.). Whitebark pine (*Pinus albicaulis* Engelm.) is a minor host for the mountain pine beetle, and it is present in portions of the Blue Mountains where the elevation exceeds 4,500 ft. Limber pine (*Pinus flexilis* James), found in isolated occurrence in the Blue Mountains, is also a minor host for mountain pine beetle. A fourth major host for the mountain beetle, sugar pine (*Pinus lambertiana* Dougl.), does not occur in the Blue Mountains, nor do several other pine species which serve as minor hosts for the mountain pine beetle, in other areas; included are Coulter pine (*Pinus coulteri* D. Don), foxtail pine (*Pinus balfouriana* Grev. & Balf.), pinyon pine (*Pinus edulis* Engelm.), and bristlecone pine (*Pinus aristata* Engelm.) (Amman et al. 1985). Non-host species of genera other than *Pinus* (Douglas-fir, true firs, spruce, larch, and incense cedar) are said to be occasionally attacked, but broods rarely develop in these species, since they are not true hosts (Amman et al. 1985; Wood, S.L. 1982). Although, when pine hosts are heavily infested by mountain pine beetle, nearby nonhost trees may also be attacked (Amman et al. 1985).

Mountain pine beetle may be present in several vegetation series containing host tree species, including subalpine fir (CE/CL), grand fir (CW), Douglas-fir (CD), and ponderosa pine (CP) series. It is most common in the latter series, preferring densely-stocked, unmanaged pine stands. It may be found in lesser amounts in the other series when overstocking, disease, drought, or other factors weaken hosts. Most mountain pine beetle damage occurs in mature or overmature, overstocked stands of lodgepole pine. Lodgepole pine accounts for 95% of the host species killed by mountain pine beetle in the United States (McGregor 1985a). Since the 1970's, extensive thinning of second-growth ponderosa pine stands has reduced beetle-caused losses, but increases in net yield over the past few decades have increased intertree competition, creating stand conditions more favorable to attack by beetles. The present influence of drought has led to increased mountain pine beetle-caused ponderosa pine mortality in many areas throughout the Blue Mountains.

Biology

The life cycle of the mountain pine beetle can be divided into three major phases: Migration, colonization, and development (Raffa 1988). Migration begins when adult beetles emerge from trees successfully attacked the previous season. This is a dispersal (migration) flight in which beetles seek out new suitable host trees in which to produce brood. Flights occur during July and August.

The colonization phase begins with the initiation of attacks on host trees by unmated female beetles. Apparently, initial arrestment of flight on a tree has more to do with visual cues and vertical bole orientation than host chemistry (Raffa 1988). Chemical cues are more important in initiating attack by female beetles tunneling into the bark (Raffa and Berryman 1982). In the presence of a certain host monoterpene (from oleoresin contained in resin canals), the female beetle produces attractant compounds or aggregating pheromones as she feeds, which draws in enough beetles to overcome the natural resistance of the tree and ensures mating. Adjacent trees are also usually infested, due to the large number of beetles drawn in from surrounding areas. Other compounds, termed antiaggregants, are produced as a mechanism to limit the extent and duration of the beetles' attack on a particular host, thus avoiding overexploitation of the food resource (Wood, D.L. 1982). Beetles kill host trees through mining in the phloem, and through the introduction of a blue stain fungus which develops and spreads through the sapwood, interrupting the flow of water to the crown. The fungi also reduce the trees' flow of pitch, thus aiding the beetle in overcoming the oleoresin exudation pressure that functions to defend the tree by "pitching" the beetles out. Upon entering the tree, female beetles must work to continuously remove the resin that flows into the wound. Otherwise, it would force her from the gallery, or form a pitch tube, entombing her. Such an induced defense reaction of the tree to wounding by bark beetles is also believed to provide an active process of protecting the tree from the invading beetle-fungus complex by forming necrotic lesions at, and around the site of infestation/infection (Raffa 1988). When beetles first enter the tree, they force reddish-brown boring dust and fecal pellets (frass) from the gallery, which then accumulates in bark crevices and around the base. Later, during construction of the egg galleries, the frass is packed in the gallery.

Mating takes place beneath the bark and female beetles soon begin constructing a vertical gallery in which she lays eggs. Up to 260 eggs may be deposited in a single gallery, but the usual number is around 75 (Raffa 1988). Though not too common, female beetles may re-emerge from the bark and attack other trees once oviposition is complete. Eggs hatch in about 7-14 days depending on weather conditions.

The development phase begins with egg hatch. The larvae mine the phloem tissue near the cambium interface at right angles to the egg gallery, sometimes etching the sapwood slightly. Development of larvae usually proceeds to the second or third instar by the time winter temperatures halt further development. Resumption of feeding and development begins again in mid or late spring. A small pupal cell is constructed by the final instar at the end of the gallery. Larvae usually transform into pupae and then into adults about July, after spending about 3 weeks within the pupal chamber. Adults feed within the bark for a short time before emerging. Mountain pine beetles normally go through one generation per year throughout most of the Blue Mountains. Overlapping broods can result in both larvae and adults overwintering. Needles on successfully attacked trees may begin fading within a few months, and crowns fully fade to a rusty brown color within a year of first being attacked.

Outbreaks of mountain pine beetle are limited by food supply, tree resistance, predators, parasites, intra- and inter-species larval competition for food and space, and by unseasonably low temperatures. The influence of these factors on outbreaks of mountain pine beetle is discussed elsewhere (Amman et al. 1985). But it should be noted that a number of the natural enemies of mountain pine beetle also utilize the attractants produced by beetles to locate their prey (Wood, D.L. 1982).

History

Mountain pine beetle outbreaks have been observed in the Blue Mountains and on adjacent areas on the Payette National Forest in Idaho since as early as 1906 and 1907 (Burke 1990). On August 17, 1907, an infestation of mountain pine beetle was discovered near Joseph, Oregon by H.E. Burke. It was said to be one of the starting points of the epidemic that occurred in the Blue Mountains between 1907 and 1912 (Burke 1990). During the preceding 3-year period, it was estimated that 90 to 95 percent of the lodgepole pine and much of the ponderosa pine had been killed on an area exceeding 100,000 acres. By 1910, host species were dying near Baker, Oregon; around Anthony Creek on the Whitman National Forest; and near Austin on the divide between the Powder and the John Day Rivers.

Records documenting mountain pine beetle outbreaks and infestations in the Blue Mountains from the period 1912-1938, and from about 1942-1949 could not be researched and summarized here due to limitations of time and availability of historical records and reports. Most historical information is likely to be found in unpublished reports in various office files scattered among Forest Service offices, the Pacific Northwest Region and Pacific Northwest Research Station, and the Oregon Department of Forestry.

Apparently, during the period from 1938 through 1942, mountain pine beetle populations were actively killing large amounts of trees only in the Cascade Mountains of Oregon and Washington. In the Blue Mountains, losses were reported to be very low in 1936, but increased in 1937 and 1938, followed by a steady decrease each year until, in 1942, losses were reported to be the lowest recorded over a 12-year period.

The available historical record on mountain pine beetle infestations between 1942 and 1949 is incomplete. But beginning in 1949, Aerial Forest Insect Detection Surveys commenced and provide a record of insect conditions in the Blue Mountains from that time on. Survey records, though complete, should not be misinterpreted to mean that all host species within the acreage figure reported were killed by the mountain pine beetle. Acreage trends depict "areas of infestation" in which the intensities of mountain pine beetle-caused tree mortality varied from year to year and place to place.

Based on aerial surveys Mountain pine beetle infested 10,450 acres in the Blue Mountains in 1949. During the following two years, outbreaks were reported in noncommercial stands of lodgepole pine and stagnated second-growth ponderosa pine in various places in the Blue Mountains, but acreage figures were not available. No mountain pine beetle infested acreages were reported for the Blue Mountains in the aerial survey reports for the years 1952 and 1953.

The mountain pine beetle-infested acres reported in the annual survey reports were used to construct the mountain pine beetle trend from 1950 to 1990 (Fig. II-10). Though the acres of infested host are reported for the year the survey was conducted, it should be noted that the majority of mountain pine beetle-killed trees observed were actually attacked the previous season. Beetle-attacked trees usually remain green or barely start to fade by the end of the season they are attacked, so most current mortality is not visible from the air that season, and doesn't get mapped until the following year's Aerial Insect Detection Survey flight. It is also important to note that the acreages reported are probably underestimated because some of the data for portions of the North-half of the Umatilla National Forest, (on the Washington state side) were not available for preparation of the figure.

The mountain pine beetle trend (Fig. II-10) shows minor outbreaks occurring through the 1950's and into the mid-1960's. Beginning in about 1967, however, the second largest outbreak of mountain pine beetle on record in the Blue Mountains started in mature, overstocked lodgepole pine, in the upper reaches of the Grande Ronde River, near Johnson Rock. Lodgepole pine stands often develop rapidly on sites disturbed by fire or other factors (Lotan and Perry 1983). However, this can lead to overstocking and the lodgepole stands killed by mountain pine beetle during the 1970's Blue Mountains outbreak undoubtedly developed in this manner.

Once the mountain pine beetle became established in lodgepole stands, the epidemic increased rapidly in magnitude: Eventually it involved vast areas on all three Blue Mountains National Forests and interspersed and adjacent state, private, Bureau of Land Management, and Indian Reservation lands. In other words, the epidemic was apparent nearly everywhere concentrations of host occurred. In practical terms, the mountain pine beetle nearly wiped out every mature or overmature stand (and even many small sawlog-sized stands) of lodgepole pine within the bounds of the infestation. And as the lodgepole became depleted in some areas, the beetles "switched" to other host species. This is evidenced by the fact that mortality to stagnated second-growth, and even some mature stands of ponderosa pine, eventually followed a similar rapid increase after remaining more or less at

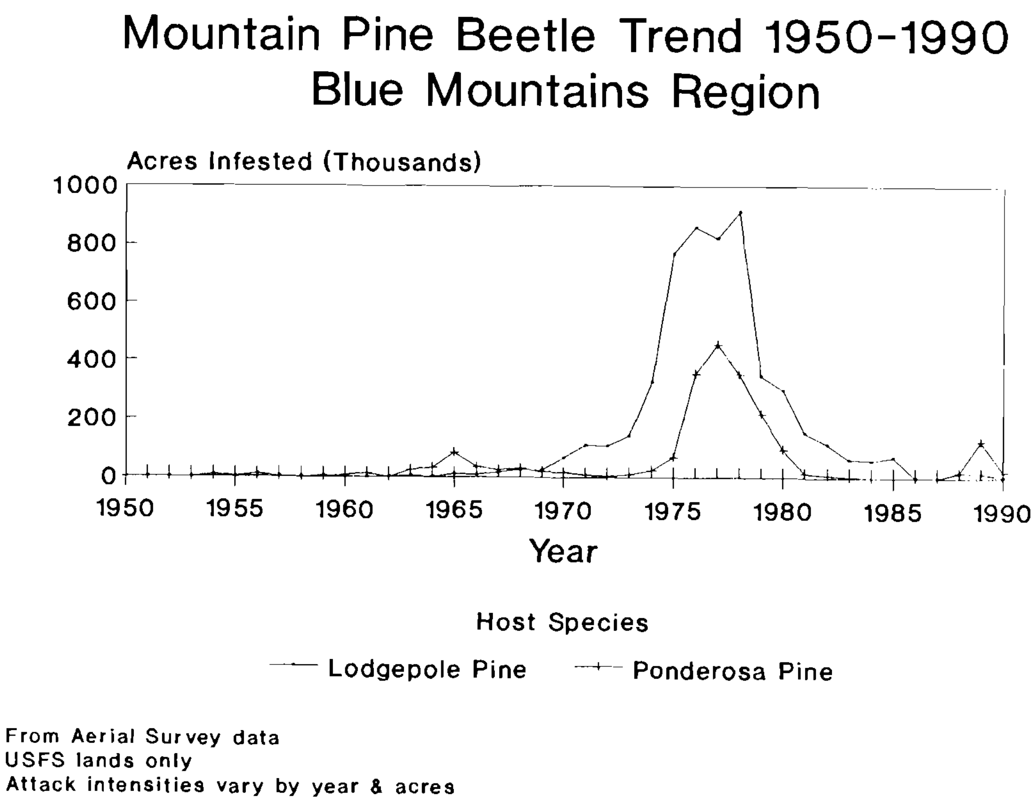


Figure II-10
Mountain pine beetle infestation trend from 1950 thru 1990 on National Forest lands (Malheur, Umatilla, and Wallowa-Whitman) in the Blue Mountains. (Based upon Aerial Insect Detection Survey data)

equilibrium levels for several years. To sum up, the outbreak began in 1967, peaked in the mid- or late-1970's, and terminated during the early 1980's, leaving hundreds of thousands of acres of lodgepole pine dead or dying, a condition that some have described as "a sea of red in the forests."

Thinning experiments in dense stands of second-growth ponderosa pine which began in the 1960's, were beginning to yield promising results during the 1970's, illustrating that the technique could well be used as a silvicultural manipulation to minimize mountain pine beetle problems in treated stands (Sartwell and Stevens 1975). Accordingly, extensive thinning of second-growth ponderosa stands was carried out during the 1970's with the result of drastically reducing beetle-caused losses (McGregor 1985a). Now, some 20 or more years have passed since many of the ponderosa pine stands were thinned, and mountain pine beetle populations are beginning to increase again (Fig. II-10), because stand susceptibility increases as crowns close, and competition for light, space, water, and nutrients increases. In these stands that are set up for beetle attack again by virtue of their size and high stocking densities, several years of drought have provided enough stress to tip the scales in favor of the beetle, and begin another wave of mountain pine beetle-caused mortality: But this time the epidemic will center in ponderosa pine, in part because the majority of the susceptible mature lodgepole pine stands were destroyed by the beetle during the 1970's outbreak.

It is interesting to note that peaks of mountain pine beetle infestations in ponderosa pine have occurred at exactly 12 year intervals since 1965: Possibly, this is the partial result of alternating applications of thinning in dense stands with periods of growth back to a point of high susceptibility to mountain pine beetle. It is probably also related to drought conditions.

Stand Conditions

The stand conditions conducive to mountain pine beetle outbreaks vary in relation to the host species being attacked. Since these factors are more completely reviewed elsewhere (Amman et al. 1977; McGregor and Cole 1985) they will not be discussed in detail here.

Many studies and observations over the past 50 or more years have shown that most mountain pine beetle outbreaks start in stands which: (1) Are pure or nearly pure; (2) are essentially even-aged; (3) have average tree diameters exceeding 7 inches DBH; and (4) have stem basal areas exceeding 150 sq. ft. per acre (Dolph 1982; Sartwell and Stevens 1975). Once an outbreak begins, beetles select the largest trees in a stand. The natural resistance of trees and stands to attack by mountain pine beetle decreases as age and competition increase; Also, weakening by disease or other insect damage, wounding, droughty conditions, soil compaction and displacement, and fire and other disturbances can all act to limit a tree's resistance to attack.

It has also been suggested (Bartos and Amman 1989) that a stand's microclimate might play a significant role in its susceptibility to mountain pine beetle. In their study, Bartos and Amman (1989) found that by thinning lodgepole pine stands, the increased light intensity, wind movement, insolation, and temperature within the treated stand presented an environment unfavorable to mountain pine beetle. Moreover, they suggested that as crown closure begins to occur in partial cut or thinned stands, a favorable microclimate may occur and invite beetle attack, regardless of tree vigor.

Research information, observations, and experience have allowed development of some generalizations regarding the risk of stands to attack by mountain pine beetle in the Blue Mountains and elsewhere in the Pacific Northwest Region. For example, white pine stands become "high risk" when average DBH is 16 inches or more, age is 140 years or older, basal area is 150 square feet per acre or more, and tree vigor index (Waring and Pitman 1980) is less than 50 grams per square meter of foliage. Ponderosa pine stands are at high risk of attack by mountain pine beetle when average DBH is 8 inches or more, age is 50-100 years, basal area is 150 square feet per acre or more, and tree vigor index is less than 50 grams per square meter of foliage. Lodgepole pine stands are at high risk when average DBH is 8 inches or more, age is 80 years or older, basal area is 100 square feet per acre or more, and tree vigor index is less than 50 grams per square meter of foliage.

Occurrence

There has been a generally increasing trend in infested acreage by mountain pine beetle since World War II (Sartwell and Stevens 1975). During the past three decades, mountain pine beetle outbreaks have resulted in infestation of tens of thousands of acres annually in the Blue Mountains (Fig. II-10). From 1961 through 1990, the acres of lodgepole pine infested annually by the mountain pine beetle on Forest Service lands in the Blue Mountains averaged over 180,000 acres per year, and acres of ponderosa pine averaged over 70,000 acres per year. However, these figures are qualified by the fact that infestation intensities vary considerably from acre to acre and from year to year. In some instances this has resulted in double-counting of infested acres where lodgepole pine and ponderosa pine occur together on the same acreage and portions of both hosts were attacked by mountain pine beetles the same year. The fact that infestation intensities vary means that a 5-acre area with only 5 scattered host trees killed by mountain pine beetle counts the same in terms of number of acres infested as a similar 5-acre area having 500 host trees killed by the beetle.

It is also useful to keep in mind our definition of an "outbreak," as distinguished from an "infestation." Here, we use "outbreak" in the same context as Sartwell and Stevens (1975) to mean the "group killing of three to five or more adjacent trees in a single season as signifying the lower limits of outbreak conditions." The term as used by Sartwell and Stevens, applied to the insect problem in ponderosa pine only; whereas, the definition of an "outbreak" in lodgepole pine might be based upon different levels of tree mortality. This distinction is due in part to the historical trend of economically valuing lodgepole pine less than ponderosa pine from the standpoint of fiber production. We use the Sartwell-Stevens definition in a less restrictive, non-economic manner, to apply to lodgepole pine as well as ponderosa pine, since in either case the level of mortality threatens the ability to achieve short-range or long-range resource management objectives, if left unchecked. An "infestation" in our usage, can apply to non-outbreak levels of tree attack as well as to outbreaks.

The Forest by Forest trends of mountain pine beetle infested acres of lodgepole pine and ponderosa pine over the past 10 years reflect changes in the relative susceptibility of stands over time. The graphs of mountain pine beetle in lodgepole pine for the Malheur, Umatilla, and Wallowa-Whitman National Forest (Fig. II-11), indicate the decline, around the mid-1980's, of the bark beetle outbreak that began in 1967. The decline of mountain pine beetle in lodgepole pine on the Umatilla National Forest appears to have occurred earlier (early-1980's), and by 1984, few acres of lodgepole pine were being infested by mountain pine beetle (Fig. II-11). After 1986, the infestation of lodgepole pine on the Wallowa-Whitman appears to have stabilized at a relatively low level (Fig. II-11). The Malheur shows a somewhat similar trend to the Wallowa-Whitman, although susceptible lodgepole pine stands on the Long Creek Ranger District have been more widely invaded by mountain pine beetle than any of the other ranger districts over the past three years (Fig. II-11). It seems reasonable to assume that the 1970's mountain pine beetle epidemic in lodgepole pine declined because the beetle had killed off most of the susceptible lodgepole pine stands, normally leaving only the much younger and smaller diameter stands which are largely unaffected by the beetle. This, in spite of four or five years of drought which might be expected to have some negative influence on the susceptibility of trees to the mountain pine beetle.

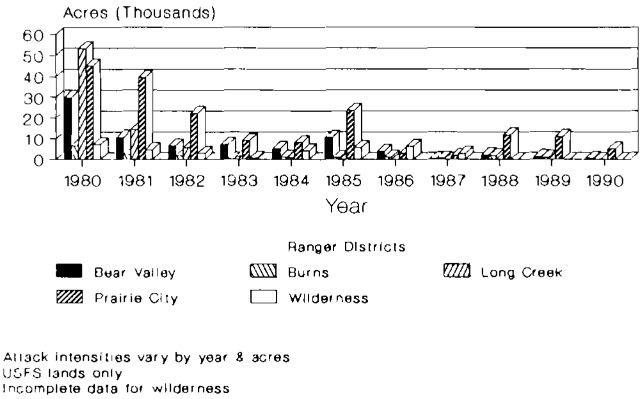
The decline of the 1970's mountain pine beetle outbreak in ponderosa pine, in contrast to the lodgepole pine, occurred very early in the 1980's on all three of the Blue Mountains National Forests (Fig. II-12). And infestations in ponderosa pine remained relatively low until the late 1980's, when increased acreages of ponderosa pine began to be infested by the mountain pine beetle on the Malheur and the Wallowa-Whitman (Fig. II-12) National Forests. Lower levels of mountain pine beetle activity in ponderosa pine have occurred on the Umatilla National Forest over the past 3 years (Fig. II-12). The implications of these data are that stands of ponderosa pine have become more susceptible to mountain pine beetle in recent years, especially on the Malheur and Wallowa-Whitman National Forests, and are in need of treatment to reduce mountain pine beetle susceptibility.

Suppression

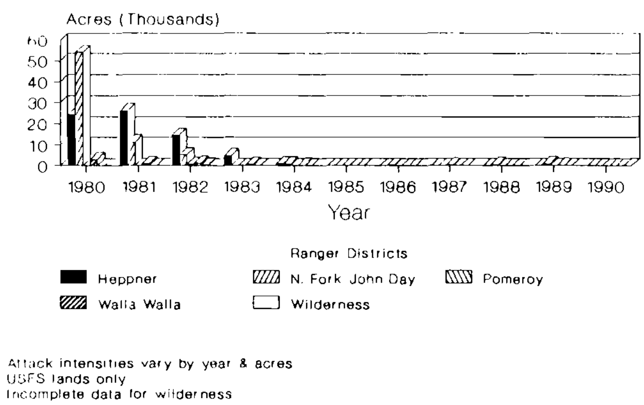
Control activities for mountain pine beetle have changed over the years from a strategy of direct control, principally by felling and burning infested trees, to the current (outbreak prevention) philosophy of bark beetle control through forest management practices. A complete review of control methods is beyond the scope of this report. A number of methods have been tried at various times and places, with variable success, most of these have been described by Keen (1952), Miller and Keen (1960), and others.

The earliest efforts at bark beetle control in the Blue Mountains was the Northeast Oregon bark beetle control project of 1910-11, as described by Burke (1990). Although various other efforts were made during subsequent years, this is the only one that will be mentioned, mainly because it is of historical interest in that it accounted for several "firsts" in pest control efforts in the Pacific Northwest. The significance of this bark beetle control effort lies in the fact that it was the first forest-insect-control project undertaken; it was the first endeavor in which the U.S. Department of Agriculture's Bureau of

Mountain Pine Beetle Infested Acres
Lodgepole Pine
Malheur National Forest



Mountain Pine Beetle Infested Acres
Lodgepole Pine
Umatilla National Forest



Mountain Pine Beetle Infested Acres
Lodgepole Pine
Wallowa-Whitman National Forest

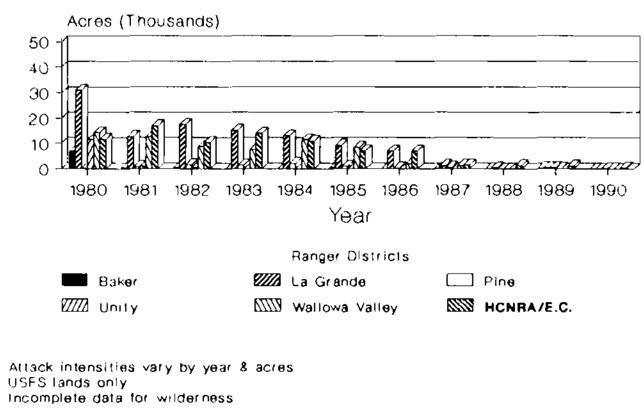
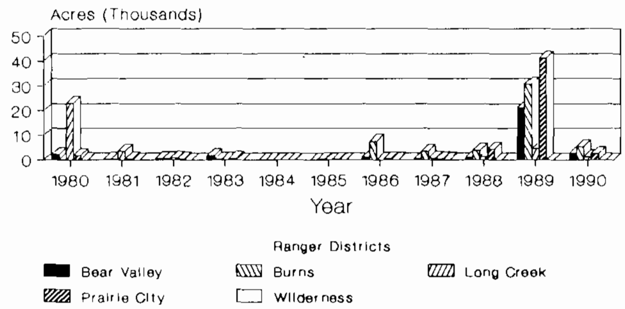


Figure II-11

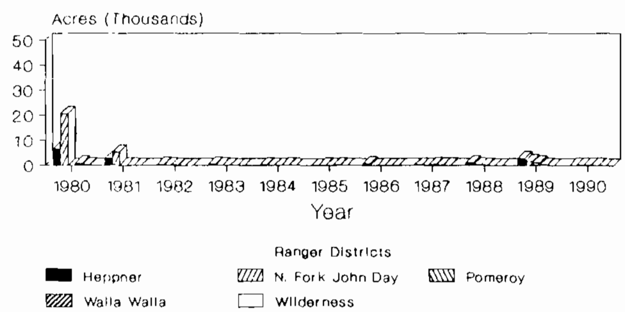
Acres with visible mountain pine beetle-caused lodgepole pine mortality on National Forests in the Blue Mountains from 1980 thru 1990. (Based upon Aerial Insect Detection Survey data)

Mountain Pine Beetle Infested Acres
Ponderosa Pine
Malheur National Forest



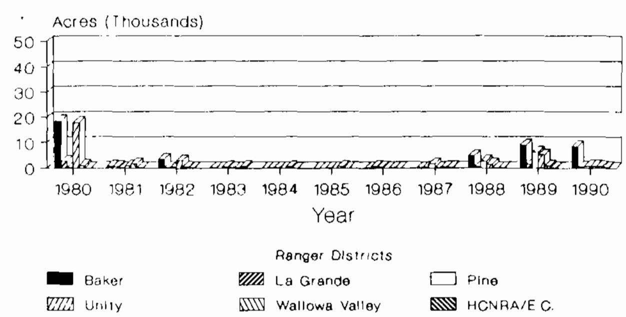
Attack intensities vary by year & acres
USFS lands only
Incomplete data for wilderness

Mountain Pine Beetle Infested Acres
Ponderosa Pine
Umatilla National Forest



Attack intensities vary by year & acres
USFS lands only
Incomplete data for wilderness

Mountain Pine Beetle Infested Acres
Ponderosa Pine
Wallowa-Whitman National Forest



Attack intensities vary by year & acres.
USFS lands only
Incomplete data for wilderness

Figure II-12

Acres with visible mountain pine beetle-caused ponderosa pine mortality on National Forests in the Blue Mountains from 1980 thru 1990. (Based upon Aerial Insect Detection Survey data)

Entomology and Forest Service cooperated with private timber companies; it was the first time funds were appropriated by Congress to combat a specific forest-pest outbreak; and it was the first large-scale effort to control an outbreak of the mountain pine beetle in lodgepole pine in the United States (Burke 1990; Craighead et al. 1931).

Other methods that have been used to prevent or suppress mountain pine beetle outbreaks have included sanitation and salvage of stands, thinning of low- and moderate-hazard stands, and more recently, use of synthetic beetle attractants to manipulate and monitor small outbreaks (McGregor 1985a). Chemical insecticides have also been successfully used to treat high-value trees located in campgrounds or other administrative sites, and protect individual standing live trees from lethal bark beetle attack (Shea 1989). An Array of chemical pesticides have also been used in the past in attempts to kill beetles once they have successfully colonized a tree: But, like felling and burning infested trees, this has proven to be an expensive and futile endeavor.

Although the use of semiochemicals (chemicals that influence the behavior of both destructive and beneficial insects in the environment) have shown great promise in manipulating destructive bark beetle populations, registration with U.S. Environmental Protection Agency of certain potentially useful semiochemicals such as verbenone, the antiaggregrating pheromone of the mountain pine beetle, is still pending. For now, these pheromones may only be use under an Experimental Use Permit (Hamel 1989). However, the use of bark beetle baits or attractants for "trap cropping" is permitted without the need for EPA registration. This strategy allows the direct baiting of standing green or "downed" trees with pheromones to concentrate bark beetle populations in the tree prior to harvesting out the infested trees.

Effects

Various resources can be expected to be affected to greater or lesser degrees by mountain pine beetle epidemics. Those who witnessed the devastation of the 1970's mountain pine beetle outbreak in the Blue Mountains know all too well the destructiveness of this bark beetle across the resource spectrum. All unmanaged stands of mature and overmature lodgepole pine, of second-growth mature and overmature ponderosa pine, of mature and overmature western white and sugar pines, and of overmature whitebark and limber pines are susceptible to attack (McGregor 1985a). Rapid salvage of beetle-killed trees is essential for maximum recovery of wood fiber. Blue staining of the sapwood occurs within the first year of attack, degrading the wood (although there have been premium markets for this wood at various times past). Though blue-stained wood is structurally sound and has no defect related to the stain, other fungal organisms introduced by the beetles cause sapwood or heartwood deterioration, and can render wood totally useless for wood fiber unless salvaged within three to five years after the tree dies (McGregor 1985a). The earlier the wood is salvaged, the more volume will be recovered.

The Blue Mountains contain thousands of acres of overstocked second-growth ponderosa pine stands that are not planned for immediate timber harvest. Some stands are undergoing various stages of treatment to control stocking, to improve vigor and growth, and reduce susceptibility to bark beetles. But if a mountain pine beetle outbreak develops in stands that have not been treated for various reasons, are deferred, or are inaccessible, the potential losses could be substantial. In addition, significant portions of forested areas can be left non-stocked or under-stocked following an outbreak of mountain pine beetle. Some commercial timber lands could take years for sites to reforest naturally, without some major disturbance of the site, such as caused by fire.

Watersheds that are damaged by mountain pine beetle outbreaks undergo changes that significantly affect water yield, sometimes for many years. After an infestation collapses, the water yield may increase as much as 30 percent and the increase could last as long as 15 years, while new stands are becoming re-established on affected sites (McGregor 1985a). Melt rates and peak runoff would both be expected to increase as infested trees are removed and openings are created (McGregor 1985b). And construction of roads to salvage timber could result in increased sedimentation and lowering of water quality.

Wildlife habitat is changed as the mosaic of live tree and forest openings changes in response to mountain pine beetle infestation. Bark beetle outbreaks can affect elk and mule deer by altering the arrangement and abundance of food, cover, and other key components of habitat, thus altering wildlife use patterns (Light and Burbridge 1985). As dead trees fall and "jack-straw," the increase of dead woody accumulation on the forest floor can inhibit elk and deer use, and eventually predispose large areas to stand replacement fires. Snags created by mountain pine beetle epidemics will benefit species that use snags.

Increased risk of wildfires through the buildup of fuels is directly influenced by mountain pine beetle epidemics. The Corral burn on the Malheur National Forest during the late summer of 1990 was aided by an abundance of lodgepole pine fuels created by a recent epidemic of the mountain pine beetle.

Mountain pine beetle epidemics can result in significant impacts on recreation resources. Outbreaks developing in stands that include developed recreation sites such as campgrounds, have killed so many trees that campgrounds have had to be abandoned or moved (McGregor 1985a). Dead standing snags eventually fall over, presenting great risk of injury to individuals and property. Also, a large number of acres of dying and dead lodgepole pine or ponderosa pine, causes a negative visual effect, even in stands that have considerable amounts of other species (McGregor 1985b).

One benefit provided by mountain pine beetle epidemics is the improvement of range resources through the opening of closed stands of lodgepole pine and the resulting increases in forage.

Hazard Rating

Identification of stand hazard and risk with respect to the mountain pine beetle will help in designing and accomplishing sound multiple resource management in those stands susceptible to mountain pine beetle. Unfortunately, methods to reliably predict when an outbreak will develop are not available (Shrimpton and Thomson 1981), but stand susceptibility and extent of losses can be predicted (Amman and McGregor 1985).

Systems to hazard rate stands have been developed for most lodgepole pine, ponderosa pine, and western white pine stands in Oregon and Washington. Several of these have been used successfully in various parts of the Blue Mountains to accurately predict mountain pine beetle susceptibility. And once a stand's relative susceptibility is known, losses caused by the beetle can be reduced by establishing thinning or harvesting priorities and treating the highest risk stands first (Dolph 1982).

Waring and Pitman (1980) have hypothesized that the amount of carbohydrate reserves available to the tree is the basic physiological factor that controls host resistance, and therefore decline in stemwood production would indicate a carbohydrate reserves limitation, meaning there might not be enough to adequately protect the tree from beetles. Furthermore, they have developed a means of accurately estimating growth in stemwood volume and proposed that trees with high resistance would produce relatively large amounts of sapwood each year, whereas susceptible trees would produce much less. This study forms the basis for a method of vigor-rating stands to determine the relative susceptibility to mountain pine beetle.

Though originally developed for predicting the mountain pine beetle susceptibilities of lodgepole pine stands, the Waring-Pitman method has been adapted for vigor-rating ponderosa pine stands as well.

During and following the 1970's mountain pine beetle outbreak on the Wallowa-Whitman and Umatilla National forests, Bob Dolph (retired Forest Pest Management Entomologist) compared the Waring-Pitman Tree Vigor Index method to three other widely used systems for assessing the susceptibility of ponderosa pine to bark beetles: Keen's Tree Classification System; The Penalty System of Rating Risk; and the Periodic Growth Ratio Method. His results showed that among the four techniques evaluated, the Tree Vigor Index method was the most sensitive in identifying trees susceptible to beetle attack (from "Identifying Mature and Overmature Ponderosa Pine Most Susceptible to Mountain Pine Beetle Attacks in Northeast Oregon;" Robert E. Dolph. Unpublished, undated report on file at Forest Pest Management, Pacific Northwest Region, Portland, OR).

Another method of predicting stand susceptibility to mountain pine beetles that has been developed is based on elevation, latitude, age, and average DBH (Amman et al. 1977). This system is used for unmanaged lodgepole pine stands in the Rocky Mountains. The applicability of this method to stands in the Blue Mountains is unknown.

Various other methods have been developed to hazard-rate stand susceptibility to mountain pine beetle, but it is beyond the scope of this report to mention them all. Amman and Anhold (1989) have evaluated these numerous methods and conclude that the best results in predicting hazard or risk will be achieved on an individual stand basis, and that tree size (positively related to tree mortality) and stand density (negatively related to tree mortality) will be important variables in any hazard- or risk-rating system.

Models

Models to estimate mountain pine beetle population dynamics and damage have been developed by Cole and McGregor (1983) and Burnell (1977). Another model, The Mountain Pine Beetle Model (Crookston 1979), has brought both the rate of loss model by Cole and McGregor, and the population dynamics model of Burnell, together in a computer program. The Mountain Pine Beetle Model, when linked with the Stand Prognosis Model (Stage 1973), can predict growth and development of lodgepole pine stands while simulating the losses due to mountain pine beetle epidemics. The shortfall of all these models is that they are limited to estimating losses and simulating population dynamics of mountain pine beetle in lodgepole pine stands only. There are no models to predict mountain pine beetle damage in ponderosa pine stands.

Management

The management of mountain pine beetle should involve an Integrated Pest Management approach, with the goal of reducing losses to tolerable levels. Prevention should be the center point of any IPM program for management of mountain pine beetle. Prevention is viewed as the best approach because its techniques are more effective, economical, environmentally acceptable, and compatible with management for other forest resources (McGregor and Cole 1985).

An array of techniques are available for use in the integrated pest management program for mountain pine beetle. The first step in management for mountain pine beetle is to determine the relative beetle damage hazard of a given stand. The characteristics of various mountain pine beetle host-species stands that have been shown to have high potential for sustaining severe damage from mountain pine beetle attacks have been presented earlier. These attributes should be used to identify those stands in the greatest need of treatment, and then the various hazard-rating methods may be used to help prioritize stands for treatment.

Hazard-rating and evaluation of the present condition of a stand, must occur before the pest management specialists, in cooperation with the District or Forest staff can recommend the appropriate treatment.

General guidelines that have been developed and used in the Pacific Northwest Region (and are applicable in the Blue Mountains) are the following:

- **Thin or harvest stands with average tree vigor index less than 50 grams of wood/m^2 of foliage.**

  Trees with vigor indices of less than 50 grams of wood have a high potential for being attacked and killed by mountain pine beetle. Stands containing many trees with low tree vigor indices should be thinned to improve growth rates or regenerated to avoid losses to beetles. At least 15 widely spaced dominant trees should be sampled.

- **Manage western white pine stands on rotations less than 120 years and avoid basal areas greater than 150 sq. ft.**

  White pine stands with basal areas less than 100 sq. ft. per acre and less than 120 years old have experienced few losses to mountain pine beetles. Stand age should not exceed 140 years, and basal area should not exceed 150 sq. ft. per acre. Thin to reduce basal area.

- **Manage lodgepole pine stands on rotations less than 80 years and avoid basal areas greater than 100 sq. ft.**

  Lodgepole pine stands with basal areas less than 80 sq. ft. per acre and less than 60 years of age have experienced few losses to mountain pine beetles. Stand age should not exceed 80 years and basal area should not exceed 100 sq. ft. per acre. Thin to reduce basal areas.

- **Second-growth ponderosa pine stands should not carry basal areas in excess of 150 sq. ft. per acre.**

  Ponderosa pine stands 50 to 100 years old, with basal areas of 150 sq. ft. or more per acre have high potential for serious losses from mountain pine beetles. Stands should be thinned to reduce basal areas. If stands are thinned to basal areas of 80 or 90, the need for intermediate entries to reduce basal areas below 150 will be reduced. High quality sites can support more basal area than poorer sites, therefore, these guidelines can be adjusted based on site quality of a particular area.

- **Harvest stands with outbreaks promptly.**

  Stands experiencing a mountain pine beetle outbreak should be promptly harvested to avoid building an even greater population of beetles and to prevent extensive losses to stain and saprotting fungi. Remove trees with pitch tubes. Foliage on trees containing mountain pine beetle broods will be green to yellow-green.

- **Spray high value trees with registered insecticides prior to beetle flight to protect them from successful infestations by beetles.**

  The insecticide, SEVIMOL, is registered for use as a preventative spray against mountain pine beetles and western pine beetles. Trees in areas experiencing tree killing by beetles can be protected from lethal attack for one year by thoroughly spraying them with ground sprays shortly before beetle flight periods in July. The sprays are strictly preventative; they will not save trees already attacked. Spraying has to be repeated on a yearly schedule until tree killing in adjacent areas subsides.

- **Do not stack pieces of beetle-infested wood against green trees.**

  Mountain pine beetles and pine engravers in recently killed trees cut for logs or firewood can emerge to attack adjacent trees. Stack piles of beetle-infested wood away from green trees in open sunlight, remove the bark, or tightly cover the pile with clear, not black, plastic to cook the beetles.

Evaluations have shown that trees killed by mountain pine beetle characteristically have grown less than 1 inch DBH in the 10 years before being attacked (Dolph 1982). Thinning in these stands before they become infested by beetles will improve growth and vigor and reduce the susceptibility to mountain pine beetle. One thinning study in the Blue Mountains (Sartwell and Dolph 1976) found that in the first 5 years after treatment, thinning reduced killing of ponderosa pine by mountain pine beetle by more than 90 percent and led to positive net stand growth. This study compared thinning at 12- by 12-ft, 15- by 15-ft, 18- by 18-ft, and 21- by 21-ft spacing with no thinning check plots. The degree of beetle resistance is proportional to the extent stands are thinned. Heavily-thinned stands are generally more vigorous and less susceptible to beetles for longer periods of time than lightly-thinned stands (Dolph 1982). Moreover, spacing studies in second-growth ponderosa pine show levels of 15 feet and wider (less than 100 sq. ft. per acre) will provide 15 to 25 years of protection from mountain pine beetle. If land managers choose to carry higher stocking reserves through narrow spacings, they will need to reenter the stand at more frequent intervals to stay below the 150-sq. ft. level (Dolph 1982).

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Spruce Beetle (Dendroctonus rufipennis (Kirby))

Hosts and Community

The spruce beetle is the most important mortality factor with respect to mature spruce stands in the Blue Mountains. Spruce beetle infests all species of *Picea* in North America (Schmid and Frye 1977). However, only two species of spruce occur in natural stands in Oregon: Sitka spruce (*Picea sitchensis* (Bong.) Carr.), and Engelmann spruce (*Picea engelmannii* (Parry) ex Engelm.). Engelmann spruce is the only *Picea* species to occur in the Blue and Wallowa Mountains, and it is the primary host of the spruce beetle in the lower 48 states.

The spruce beetle kills spruce in stands from the southern Rocky Mountains to Alaska and across Canada (Safranyik et al. 1981; Schmid and Frye 1977; Werner et al. 1977). White spruce (*Picea glauca* (Moench) Voss), is the primary host in Alaska, but spruce beetle also attacks Sitka spruce and Lutz spruce (*Picea* ex *lutzii* Little), a hybrid of white and Sitka spruce (Copes and Beckwith 1977; Little 1953), as well. Black spruce (*Picea mariana* (Mill.) B.S.P.) is less frequently attacked, does not support outbreaks, and apparently is the least preferred host of spruce beetle in eastern Canada (Hard and Holsten 1985; Morris 1958). Blue spruce (*Picea pungens* Engelm.) is also an infrequent host (Schmid and Frye 1977), but we speculate that it may be attacked when growing as an ornamental under severely stressed conditions or in close proximity to a spruce beetle outbreak in the Blue or Wallowa Mountains. Under outbreak conditions, spruce beetles may atypically attack lodgepole pine (*Pinus contorta* Dougl. ex Loud.) when it occurs in mixed stands with heavily infested Engelmann spruce. (Massey and Wygant 1954; Schmid and Frye 1977). However, in some cases where lodgepole pine has been attacked by spruce beetle, the insect has not killed the trees nor produced brood (McCambridge and Knight 1972).

Spruce beetles attack and kill trees in several different plant associations within the Blue Mountains physiogeographic province. It is especially common in the subalpine-fir/lodgepole pine (CE/CL) communities where Engelmann spruce is often strongly represented, dominating both the overstory component and the average basal area in stands found on moist sites. The infrequency of fire, coupled with low temperatures and more favorable site conditions resulting from high soil moisture retention, encourage spruce to become established and occupy these sites for long durations (Johnson and Simon 1987). Shade tolerance by Engelmann spruce allows this species to regenerate underneath an overstory canopy, thus it may be found as an understory component in many plant associations of the subalpine-fir/lodgepole pine vegetation series.

Other vegetation series in which Engelmann spruce is represented as either an overstory or understory component (or both) include the grand fir series (CW), and the mountain hemlock series (CM).

Biology

The spruce beetle is a native North American bark beetle whose tree killing potential has been well documented for over 100 years (cf. Schmid and Frye 1977). The life cycle of the beetle can vary from one to three years, depending on the temperature and elevation of the site. Schmid and Frye (1977) have reviewed the life cycle of the spruce beetle, describing the developments of populations having a one-, two-, and three-year life cycles. The majority of spruce beetle populations in the Blue and Wallowa Mountains are believed to exhibit two-year life cycles, but one-year cycle populations also exist. The one-year life cycle apparently occurs where the populations have attacked hosts on warm sites at lower elevations (Holsten et al. 1989). The one-year life cycle may predominate during hot, dry years which decrease brood development time. Generally, it is best for resource managers to assume the fact of a two-year life cycle when making management decisions (Schmid and Frye 1977).

Adults having a 2-year life cycle can emerge from host trees anytime from May to October, depending on temperature. Appearance of adults in the spring usually coincides with the melting of most of the snow from around the bases of attacked trees (Wygant and Lejeune 1967). Adults attack host material soon after emerging, with peak host-finding flights usually occurring from late May to about mid-June. Adults appearing in August to October may represent either a reemergence of parent adults or the movement of maturing brood adults to hibernation sites (Holsten et al. 1989).

Pioneering adult female beetles are attracted to trees through host odors, once a host is found, they initiate attack by boring through bark to the inner phloem-cambium region, where they begin constructing an egg tunnel. In the presence of an host-produced monoterpene, *alpha*-pinene, females produce frontalin, an aggregation pheromone (an attractant) which draws in hundreds more beetles--both male and female--to attack the tree en masse. This type of attack is the means by which beetles overcome the natural resistance of healthy green trees. Another pheromone, Methylcyclohexenone (MCH), is produced by spruce beetles when a female and male are together. 3-methyl-2-cyclohexen-1-one is the antiaggregative pheromone of the spruce beetle (Rudinsky et al. 1974), and is the mechanism which terminates attack once each female beetle has a mate.

Following attack, beetles complete construction of egg tunnels, and the mated females deposit groups of eggs (about 60 per group) in niches cut along alternating sides of each tunnel. After hatching, larvae feed outward from the egg tunnel en masse for the first two instars, and later, construct individual feeding galleries in the third and fourth instars (Holsten et al. 1989). In a one-year cycle development, larvae mature by the end of the summer, pupate and transform into adults; whereas, in a 2-year life cycle, larvae overwinter and develop into the adult stage during the next summer (Safranyik 1981). In either case, before adults can reach maturity and reproduce, they must overwinter in the young adult stage. This hibernation habit is apparently unique for the spruce beetle; it has not been recorded for any other species of *Dendroctonus* (Wood 1982). Overwintering sites of the young adults may be in the location where they pupated, or they may emerge and move to hibernation sites in the bases of infested trees. In standing timber, anywhere from 5 to 88 percent of the adult spruce beetles emerge and fall or crawl to the base of the tree, and bore into the bark near the litter line to hibernate (Holsten et al. 1989; Wygant and Lejeune 1967). In downed material, adults normally overwinter in place.

It is very difficult to identify spruce beetle-attacked trees by aerial surveys, because needles of infested trees do not usually fade or discolor within the first year following attack. Foliage begins to fade to pale green or yellow before dropping, usually the year after attack: However, some needles even remain green until the third summer, or up to 2 years after the initial infestation (Holsten et al. 1989). Needles on different branches of the same tree discolor at different times. These factors make it difficult to spot infestations from the air.

The main symptom of attack is the presence of reddish-brown boring dust in bark crevices on the bole itself, on the ground around the bases of standing trees, and in bark crevices on the lower-sides of down trees resulting from windthrow or logging residue. Windthrow and logging residuals will not generally show accumulations of frass beneath the tree nor pitch tubes on the bark (Schmid and Frye 1977). However, pitch tubes and masses may accumulate around the entrance holes of standing green-infested trees. These signs are most visible the summer following infestation and become less noticeable months later (Holsten et al. 1989).

Woodpeckers are major predators of spruce beetles, and during fall and winter their feeding activities help to distinguish beetle-infested trees. Woodpeckers often leave infested trees pock-marked, drilled, and partially debarked; these signs are easily noticed from a distance in susceptible stands, and the fresh accumulation of bark chips around the base of a tree, seen against the background of snow, is a good indication of infested trees. (Schmid and Frye 1977).

Spruce beetles prefer the habitat conditions found in injured, windfallen, diseased and stressed trees, and logging slash and cull logs. In fact, most major spruce beetle outbreaks have been traced to windthrow, logging debris, left after timber harvesting operations, or other stand disturbances (Schmid and Frye 1977; Wygant and Lejeune 1967), with widespread blowdown being especially conducive to increases in the beetle populations (Wygant and Lejeune 1967). And when such disturbed conditions occur in a heavily shaded area, the habitat becomes most favorable to the beetles, and conducive to epidemic outbreak. During periodic epidemics, apparently healthy green standing trees are attacked and killed by beetles over large areas when the supply of their favored host material (blowdowns etc.) has been exhausted. Under these situations, spruce beetles attack the largest trees in the stand; eventually, attacking smaller diameter trees as the largest trees are killed.

History

Spruce beetle epidemics have been the reported cause of widespread destruction of spruce throughout the spruce types, especially in the Rocky Mountain region, from as early as the mid-1870s (Schmid and Frye 1977). Although spruce beetle outbreaks have undoubtedly occurred as the result of periodic catastrophic stand disturbances in the Blue Mountains during pre-settlement times and shortly thereafter, no specific records of outbreaks prior to about 1954 could be found. Prior to the start of aerial surveys in 1949, most ground survey and control efforts in the Blue Mountains were occupied with major mountain pine beetle and western pine beetle outbreaks. Hence, insect problems that may have developed in the spruce-fir types prior to 1949 went largely undetected, or were not of enough significance to cause forest managers and entomologists great concern. Indeed, early reports during the period from 1949 to 1954 indicate that spruce beetle-caused losses in Engelmann spruce stands in most areas of Washington and Oregon, including the Blue Mountains, were not excessive and were too scattered to warrant the large expenditures needed for direct control.

Some salvage of spruce beetle-killed trees appears to have taken place on the Umatilla National Forest in years prior to 1955. A reference to the spruce beetle situation on the Umatilla NF, in the status report on forest insect conditions in 1955, indicates that beetle populations declined to the point that it was difficult to locate infested trees. The report goes on to state that centers of infestation on the Umatilla NF subsided as a result of salvage and natural control. The trend of spruce beetle in the Blue Mountains from 1954 to 1990 is shown in Fig. II-13.

Spruce beetle populations had increased in areas of the Blue Mountains, and reached a peak and started to decline in 1956. Surveys conducted at that time revealed a single new outbreak area on some 7,000 acres on the Wallowa-Whitman National Forest. Other areas of spruce beetle activity this year were small and scattered throughout areas where Engelmann spruce occurred. Efforts to control the outbreak consisted of promptly salvaging the infested trees, or by felling and spraying them with insecticides. Parasites and predators, especially woodpeckers, and abnormally low winter temperatures were considered to be the major factors in reducing the infestations and in keeping them in check. By 1958, these natural factors (in conjunction with direct control) had caused the decline of spruce beetle populations in the infested areas of the Blue Mountains to the point where the majority of the infestation was concentrated on a little over 3,000 acres, mostly on the north half of the Umatilla National Forest. Broods examined in trees from all of the infested areas were all found to be generally light and the trend was clearly downward from previous years. In the following couple of years, beetle populations occurred only as minor infestations in isolated stands, mostly on the Wallowa-Whitman National Forest. These infestations had little danger of spreading.

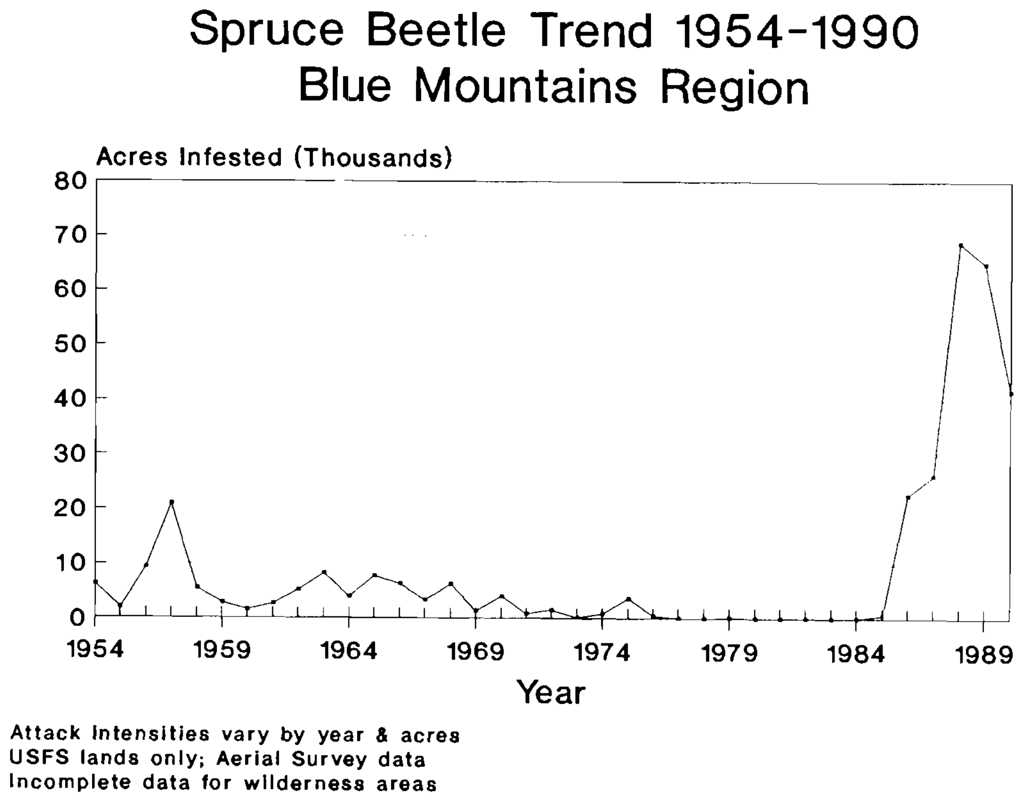


Figure II-13
Spruce beetle infestation trend from 1954 thru 1990 on National Forest lands (Malheur, Umatilla, and Wallowa-Whitman) in the Blue Mountains. (Based upon Aerial Insect Detection Survey data)

On October 12, 1962, hurricane Frieda struck Oregon and Washington, causing considerable blowdown. Downed timber was infested by beetles. Both Douglas-fir and Englemann spruce were windthrown, and were promptly colonized by beetles the following spring. In Oregon, the Umatilla and Wallowa-Whitman National Forests were the eastside Forests which contained principal infestations, while the majority of damage in Washington was on the Umatilla NF. While direct control was not viewed as necessary in 1963, infested trees were removed in accessible areas and the heavily infested areas were recommended for clearcutting. Prompt salvage of infested trees wherever accessibility would permit was key to preventing major buildup of populations. Spruce beetle populations were effectively managed using this strategy during the ensuing two decades.

Populations of spruce beetle began to rapidly increase again in the Blue Mountains following a severe windstorm that occurred in November 1981. The spruce beetle problem centered in the Lake Fork drainage north of Halfway, Oregon, on the Pine Ranger District of the Wallowa-Whitman National Forest. Spruce beetles initially infested the down trees scattered over approximately 300 acres in 1982-83, and from there populations built up to outbreak levels. Green standing timber became infested in 1984 when spruce beetles emerged from the blowdown and began attacking live trees in the surrounding stands.

Attempts were made to salvage and manage a substantial portion of the spruce beetle-infested stands in the Lake Fork Roadless Area, however, strong public opposition developed, and threatened litigation, appeals, and pending Forest Plan direction for Roadless Areas delayed treatment action that could have possibly prevented the development of an epidemic.

Spruce beetles spread into the Hells Canyon National Recreation Area, and to other locations on the Pine Ranger District. As it spread numerous stands of large, overstocked old-growth Engelmann spruce, as well as smaller spruce, were killed in the wake of the outbreak. Grouse, Sheep, Lick, Duck, and Dutchman Creeks and other drainages of the Upper Imnaha River containing concentrations of large spruce were all being affected in the course of just a few years. Spruce beetles damaged a number of popular recreation areas and campgrounds, and now has spread into portions of the Eagle Cap and Wallowa Valley Ranger Districts, virtually wiping out the susceptible spruce stands over much of the Hells Canyon NRA and in Ranger Districts on the north end of the Wallowa-Whitman National Forest.

A large supply of susceptible host material in the form of mature and overmature Engelmann spruce and several seasons of droughty weather contributed heavily to the rapid increase in both the numbers of beetles and their high survival rates. These factors effectively fanned the outbreak to alarming proportions, with devastating consequences. The tragic loss of thousands of acres of valuable spruce stands and spruce-dominated riparian areas by the spruce beetle points out the consequences of failing to promptly and effectively manage the spruce beetle problem from the outset. And, equally disturbing is the increased vulnerability of residual stands to loss by catastrophic wildfire, as a result of the significant increase in fuels created by the standing beetle-killed trees. Indeed, the 1989 fire season on the Wallowa-Whitman National Forest was one of the worst in history, and the Canal Fires which burned 23,350 acres that year, occurred in subalpine fir and Engelmann spruce stands, some of which had been previously killed, or were in the process of being killed, by the spruce beetle. The serious direct and indirect consequences of spruce beetle epidemics reaffirm the need to promptly salvage these infestations before they grow to unmanageable size and destructiveness. Given the present damage, it will require decades for these affected areas to recover.

Stand Conditions

Stand susceptibility to spruce beetle is related to a number of factors. These factors have been identified by Knight et al. (1956). Susceptibility of spruce stands decreases in accordance with the following order of these factors: (1) Spruce located in creek bottoms; (2) better stands of spruce on benches and high ridges; (3) poorer stands on benches and high ridges; (4) mixed stands of spruce and lodgepole pine; and (5) stands containing all immature spruce. After analyzing past spruce beetle outbreaks, Schmid and Hinds (1974) determined that the following stand characteristics tend to be associated with outbreaks: (1) Single- or two-storied stands; (2) high proportions of spruce in the overstory; (3) basal area of 150 square feet per acre or more in older and larger trees; and (4) an average 10-year periodic diameter growth of 0.4 inch or less.

Although spruce beetles generally prefer downed spruce over standing green trees, and endemic populations are maintained in windthrown trees (Holsten et al. 1989), populations of beetles increase to high levels when this favored host is used up. The sizeable populations that develop begin entering susceptible, large diameter standing green timber within, and adjacent to, stands containing the previously infested blowdown. This is the beginning of an outbreak of spruce beetle.

Large diameter (> 18 inches dbh) trees in mature stands with trees over 120 years old appear to be most susceptible to beetles, and are frequently the first in the stand to be attacked. Large trees are preferred to small diameter trees (6-8 inches dbh), provided they are relatively free of live branches in the basal section and grow in a competitive stand where natural pruning occurs. (Schmid and Frye 1977). However, as these age- and size-classes of spruce are utilized by beetles, smaller diameter trees down to (< 8 inches dbh) are attacked.

Although tree diameter is one of several important factors relating to the spruce stand susceptibility to spruce beetle, the importance of this factor may be more closely related to the growth rates, than it is to a simple measure of diameter. This due to the fact that the growth rate is more of an expression of tree vigor than is the size of the tree. Recent studies conducted on white spruce in Alaska (Hard et al. 1983) found that the first trees that were killed by spruce beetle at the beginning of an outbreak were larger than average in diameter but had slower than average growth in their last 5 years, whereas other spruce that were larger than average, but were less frequently killed by spruce beetles, had faster than average radial growth in their last 5 years. Additional studies (Hard 1985) also showed that slowly growing spruce were more likely to be attacked by spruce beetle than rapidly growing spruce. This evidence from these studies suggests that the spruce beetles' tree selection is based more on the factor of recent growth rate than on some diameter constraint. In addition, Hard (1985) suggests that stand resistance to spruce beetle could be enhanced by decreasing stocking to reduce tree competition and increase vigor of residuals.

Occurrence

Outbreaks of the spruce beetle in the Blue Mountains and elsewhere are closely tied to major stand disturbances such as windstorms and logging activities that leave large-sized residues in the woods, especially in shaded condition. The occurrence of the most recent spruce beetle epidemic of the past decade in the Blue Mountains can be linked to at least one of these events--windstorm.

Although all three of the National Forests in the Blue Mountains contain habitat types that support concentrations of Engelmann spruce, the majority of these areas occur on the north halves of the Umatilla and Wallowa-Whitman National Forests. Consequently, these are the portions of the Blue Mountains region which experience greatest losses due to spruce beetles during periods of epidemic buildup.

Historic survey records dating back to the 1930's for the region consistently indicate small, and insignificant spruce beetle-caused losses on the Malheur National Forest up to the present. For any one year during this period, spruce beetles infested no more that about 340 acres of spruce host that could be mapped on the Malheur National Forest, and during the majority of years, spruce beetle infested acres could not be identified from aerial surveys. Spruce drainages on the Malheur National Forest are limited in size, and perhaps more isolated from other such drainages: From this, as well as from the historical record, the conclusion can be drawn that spruce beetles will not likely be a significant threat to Englemann spruce stands on the Malheur NF in the future. Although small areas up to several hundred acres in size, could continue to be periodically infested over time as stand disturbing events continue to occur.

The Umatilla and Wallowa-Whitman National Forests, on the other hand, have had outbreaks of spruce beetle in the past that have ranged from several thousand acres up to almost 70,000 acres for any one aerial survey year. And these outbreaks have sometimes lasted 10 years or more. Due to the many factors involved, it is not known how long spruce beetle outbreaks can last in any given situation. But it should be noted that the resistance of younger and smaller trees that are attacked, the effectiveness of natural enemies in reducing beetle numbers, prompt use of early and effective control methods, and other factors all contribute to the decline of spruce beetle populations, and control the duration of epidemics once beetles build to outbreak.

Over the last 10 years, very little spruce beetle activity has been identified through aerial surveys on the Umatilla National Forest (Fig. II-14). There may be more spruce beetle activity in the next few years around the Tollgate area (Walla Walla Ranger District) on the Umatilla NF, due to a severe windstorm during January 8, 1990 that blew down subalpine fir, Englemann spruce, and other conifer species in numerous scattered locations over the area. While activity to remove some of the blowdown proceeds, monitoring in a few of the locations has not revealed populations of spruce beetle beginning to build anywhere in the area. Spruce beetle monitoring will continue to be done over the area of the blowdown to determine if, when, and where populations might build up, especially since the district has opted to remove only portions of the windthrow from some of the areas. This decision was made due to the very scattered and inaccessible nature of the windthrow throughout the stands, and in response to public opposition in applying aggressive stand treatments.

The occurrence of spruce beetle in Englemann spruce stands over the last decade on the Wallowa-Whitman National Forest is shown in Fig. II-14. Following the November 1981 windstorm that spawned the spruce beetle outbreak, it was several years before green standing trees were attacked and crowns had faded to the point that they were visible to aerial survey personnel. Accordingly, the first year that spruce beetle was mapped in an aerial survey during the current outbreak was in 1985 (Fig. II-14). Some of the details of this outbreak have already been described in the History section, above. Not since the mountain pine beetle epidemic of nearly two decades ago, has one insect caused so much destruction to a single host species.

As of the current writing, populations of spruce beetle on the north end of the Wallowa Valley Ranger District appear to be static, but green trees on the south end are still being attacked; these are being picked up on existing sales. However, the situation has gotten to the point that some individuals have predicted that by the end of 1991 most of the Englemann spruce stands on the Wallowa Valley RD will either be standing dead or in the mill yard.

On the Hells Canyon National Recreation Area, new attacks by spruce beetle are still showing up, but the occurrence appears to be declining because the larger areas of more concentrated Engelmann spruce (i.e., Duck Creek, Imnaha River, Gumboot Creek, Lick Creek, etc.) have already been killed by the beetle. The remaining areas of Engelmann spruce on the HCNRA are much more scattered, smaller, and isolated, and may be missed by the spruce beetle as the outbreak wanes.

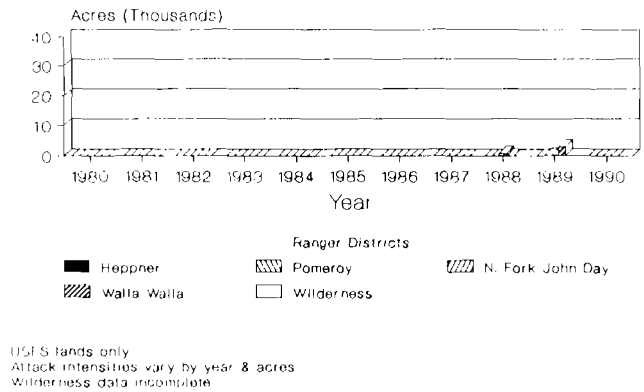
The spruce beetle has occurred on portions of the Eagle Cap Wilderness since 1986, however, epidemic buildup of spruce beetle has not been observed on the district to the west of the Lostine River yet. Even though the outbreak has reached around the north face of the Wallowa Mountains as far west as Silver Creek and up to the Lostine River.

Suppression

The primary efforts at suppressing spruce beetle populations in the Blue Mountains in the past have centered around salvaging infested trees, or failing that, felling and spraying them with insecticides. Neither method has provided satisfactory suppression except on relatively small outbreaks or when applied during the earliest stages of spruce beetle population buildup. In these instances aggressive action has been successful in treating most or all downed spruce and infested green trees.

Some of the chemicals which have been tried for controlling spruce beetle (all of which are now suspended, except for cacodylic acid, or were never registered for this use by the U.S. Environmental Protection Agency), include the fumigants para- and ortho-dichlorobenzene, chlorinated naphthalene and trichlorobenzene, ethylene dibromide, and dichloroethyl ether (Schmid and Frye 1977). Other suspended chemicals and pesticides that have been used include fuel oil, DDT, benzene hexachloride, and Silvisar 510 (cacodylic acid) (Schmid and Frye 1977). It is not known which of these pesticides have been used at various times in the past in the Blue Mountains. References to spruce beetle suppression in historical records that were reviewed in preparing this summary only made mention of the technique of felling and spraying beetle-infested trees with insecticides to suppress populations, and did not specify the insecticide(s) that were used.

Spruce Beetle Infested Acres
Umatilla National Forest



Spruce Beetle Infested Acres
Wallowa-Whitman National Forest

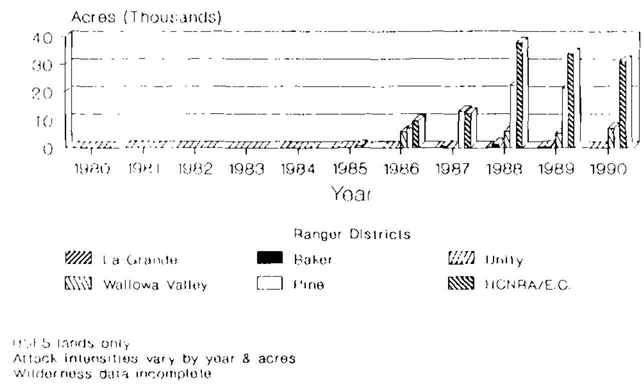


Figure II-14
Acres with visible spruce beetle-caused tree mortality on National Forests in the Blue Mountains from 1980 thru 1990. (Based upon Aerial Insect Detection Survey data)

At the present time, the only insecticides registered by EPA for treating spruce beetle-infested trees are lindane, chlorpyrifos, carbaryl, and cacodylic acid. Cacodylic acid, although it is registered as an arboricide (herbicide), is employed as an insecticide when used in a lethal trap tree application, and therefore is permissible for usage on federal lands in such cases. The related arboricide, monosodium methane arsenate (MSMA) is used in lethal trap trees in Canada (Hodgkinson 1985), but is not registered in the United States.

Various other chemicals, insecticides, and secondary wood-products industries by-products have been evaluated for their ability to protect hosts from attack by spruce beetles (Werner et al. 1983; Werner et al. 1986a; Werner et al. 1986b). Most of these chemicals show promise in protecting spruce from spruce beetles, but only a few are currently registered by the EPA for forestry use in this type of application.

The only other attempt at spruce beetle suppression in the Blue Mountains involved the use of trap trees on the infestation on the Pine Ranger District in 1986. The attempt failed, however, because the population of beetles at that time had grown to such levels that the number of trap trees that were felled could not absorb enough of the beetles to prevent the excess attracted population from attacking nearby standing trees. Also, unless trap trees are treated with insecticides to kill attacking beetles or the developing brood (which these weren't), or removed before the brood develops and emerges, the trap trees may only exacerbate the beetle problem. The trap tree method would likely have been successful had it been deployed a year or two earlier when beetle populations were still relatively small.

The majority of efforts made to address this spruce beetle problem in subsequent years has been centered on salvaging of green-infested trees and partial cutting or commercial thinning in stands where beetles have not yet become a problem. Unfortunately, in spite of the sincere efforts by the districts to manage or get ahead of the problem, the process has often resulted in the frustration of doing "too little, too late!" The time for stand management for spruce beetle prevention and aggressive action to salvage the windthrow before the beetle populations became unmanageable had long past for this outbreak.

Effects

The ecological consequence of spruce beetle outbreaks is one of altering successional patterns of stands where Engelmann spruce occurs in the Blue Mountains. Beetle-caused changes in stocking, structure, growth rate characteristics, and species composition in stands dominated by Engelmann spruce in the overstory result in an abrupt shift to more subalpine fir-dominated stands with younger spruce components. Similar patterns have led Schmid and Hinds (1974) to speculate on the affect of spruce beetle infestations on the ecological succession in the spruce-fir type in the the central Rocky Mountains. These authors hypothesize that the combined forces of spruce beetles, *Dryocoetes confusus* Swaine (a bark beetle pest of subalpine fir), and associated fungi alter the status of the spruce and fir components over the years, first toward fir, then toward spruce, and then back to fir as each species matures and spruce beetles periodically reach outbreak status (Schmid and Frye 1977). Periodic reductions of the large, dominant spruce components due to spruce beetle outbreaks in generally immature stands may tend to shift the stand more toward a single story as the stand recovers after each outbreak (Schmid and Frye 1977). In time, the further development and maturity of the spruce in these stands will reach a stage where the basal area stocking, percentage of spruce in the overstory, and diameter of spruce is such that the stand will run a high risk of spruce beetle infestation. A spruce beetle outbreak, once triggered by a major stand disturbance like windstorm, can decimate the spruce in these high-risk stands and push forest succession towards fir on affected sites. This may be the situation that occurred on the north half of the Wallowa-Whitman

National Forest, consequently partially contributing to the fueling of the current spruce beetle outbreak.

In terms of the resource impacts and effects of spruce beetle in the Blue Mountains, the current outbreak presents a pretty clear picture of the range of influences this beetle can have over a significantly large area of plant communities dominated by Engelmann spruce. The most obvious impact of spruce beetle outbreaks is to the riparian resource. These cool wet sites are typical growing sites of Engelmann spruce, and spruce growing on well-drained sites in creek bottoms represent one of the highest risk situations for spruce beetle infestation, especially when other susceptibility factors are present (see Stand Conditions, above). The effects on riparian zones and the plant and animal communities that inhabit these sites are very similar to those described for the Douglas-fir beetle, previously. The impact of spruce beetle on riparian areas might not at first glance appear to be significant on Ranger Districts in the Blue Mountains (see Appendix G). However, the data depicted in the plot of management allocations impacted by spruce beetle is partly a reflection of the relatively small proportion of total riparian zone acres on all Ranger Districts that actually represent spruce habitats. A similar argument can be made for the relatively large impacts on wilderness and special allocations. The fact is that of the total National Forest acres in the Blue Mountains in these allocations, a large proportion of them are in spruce-fir plant associations that are impacted by spruce beetle. For example, the vast majority of the "Special" management allocation acres occur on the Hells Canyon National Recreation Area, which contributes greatly to the graph for this management allocation.

Watersheds are also affected in many ways, including the amounts of streamflow, interception of precipitation, and transpiration (Schmid and Frye 1977). Although numerous studies have been made, investigators have not always been in agreement as to the extent and nature of the influences spruce beetle outbreaks have on some watershed parameters. Such differences in various watershed parameters are undoubtedly at least partially attributable to the extent and intensity of the infestation.

Forage production changes dramatically following spruce beetle outbreaks. Yeager and Riordan (1953) indicate that relatively little forage is found in mature spruce-fir forests. Beetle-killed stands, by contrast, show increased densities of grasses and sedges. And while forbs on stands killed by spruce beetle increased to 2.3 times the level found in unaffected stands, browse plants showed a steady, unexplainable decrease in this study. It is unknown how long production of forage continues to increase following an outbreak, but some suggest it could continue for a number of years (Schmid and Frye 1977).

Timber and old-growth spruce management allocations are viewed as having been, or are being, severely impacted by spruce beetle in the Blue Mountains (see Appendix G). The old-growth impacts collaborate well with the observation that spruce beetles prefer to attack the largest trees in the stand first: And as explained above (see Stand Conditions), trees in this type of stand characteristically have below average growth during the last 5 years.

Big game wildlife populations may be temporarily displaced from areas affected by spruce beetles when these stands no longer meet cover requirements or become jack-strawed. However, the increased forage production of spruce beetle-affected areas will eventually encourage increased use of these areas for forage by big game species. Other animal species such as woodpeckers would initially benefit from a large outbreak, and would increase their populations in affected areas in response to the increased supply of spruce beetles and secondary insects like woodborers, ants, other scolytids, etc. (Schmid and Frye 1977). Other insectivorous species of birds (eg. nuthatches and brown creepers) would be similarly affected.

The visual and recreational impacts of spruce beetle outbreaks are not well documented. In the case of the current outbreak on the north half of the Wallowa-Whitman National Forest however, spruce beetles have resulted in the killing of numerous large spruce trees in several campground, recreation, and administrative areas. These large, dead trees present a considerable hazard to individuals using these areas, particularly during high-use periods (summer recreation season and hunting season). These trees have had to be removed to protect the safety of individuals using the areas. The resultant removal has opened up these areas, sometimes to considerable degree, reducing the cover and privacy of individual campsites, and increasing the potential for blowdown which would endanger campers.

Lastly, fire hazard is significantly increased following a spruce beetle outbreak. The recent Canal Fires (see History, above) were fueled to a large extent by the dead trees created by the spruce beetle epidemic throughout the area. Although some (cf. Schmid and Frye 1977) would dispute the notion that fire hazard is increased due to creation of dead fuels following a spruce beetle outbreak, there are few of those who witnessed firsthand the Canal Fires, who would agree that fire hazard of spruce beetle-killed stands has been exaggerated.

Hazard Rating

Schmid and Frye (1976) developed a stand rating system for potential spruce beetle outbreaks on the basis of physiographic location, tree diameter, basal area, and percentage of spruce in the canopy. Modifying some of the earlier susceptibility categories from Knight et al. (1956), Schmid and Frye integrated these with Alexander's (1967) site indexes to develop a low, medium, and high susceptibility ratings for stands that correspond to the following risk category definitions:

(1) LOW Risk:

- o Spruce on sites with site index of 40 to 80,
- o average diameter of live spruce between 10 and 12 inches dbh,
- o basal area = < 100 ft^2 per acre, and
- o proportion of spruce in canopy = < 50 %.

(2) MEDIUM Risk:

- o Spruce on sites with site index of 80 to 120,
- o average diameter of live spruce between 12 and 16 inches dbh,
- o basal area = 100-150 ft^2 per acre, and
- o proportion of spruce in canopy = 50-65%.

(3) HIGH Risk:

- o Spruce on well-drained sites in creek bottoms,
- o average diameter of live spruce above 16 inches dbh,
- o basal area = > 150 ft^2 per acre, and
- o proportion of spruce in canopy = > 65 %.

The Stand Risk Value for a particular stand is determined by adding together the rating values (number in parenthesis associated with the risk levels, above) for each of the four stand characteristics above, to obtain the Stand Risk Value, and comparing this combined value with values from a table (see Schmid & Frye 1976) to determine the potential outbreak rating for the stand.

The system, though developed for use in the central Rocky Mountains, should be useable in the Blue Mountains. It may be necessary to adjust the system for the Blue Mountains site indices where they may differ from those used in the central Rockies. This has been done in northern Idaho and other places with good success. Unfortunately, there are no published site index tables for Engelmann spruce, based on Blue Mountains data. The table used for spruce in the Blue Mountains is based on unpublished data collected in the intermountain region (Seidel and Cochran 1981). These site index tables differ considerably from those used in the central Rockies, so adjustment of site values in the Stand Ratings for Spruce Beetles System by Schmid and Frye (1976) appears necessary to give

Stand Ratings for Spruce Beetles System by Schmid and Frye (1976) appears necessary to give accurate results. To improve the usefulness of the stand rating system to forest managers, a computer program was written to calculate stand susceptibility from the stage II inventory data of the central Rocky Mountains (Logan et al. 1980). This program would have to be modified to run from Region 6 inventory data because this Region uses a different resource inventory system.

Models

Presently there are no computer models to simulate spruce beetle population dynamics or spruce beetle-caused losses to Engelmann spruce in the Blue Mountains. A pest extension model for the spruce beetle, if added to the PROGNOSIS growth and yield simulator would be useful to help predict spruce volume losses caused by the spruce beetle. Perhaps this pest extension could be added to the pest modeling system sometime in the future.

Management

The present management strategies for spruce beetle are aimed at either prevention or suppression of infestations. The methods developed for managing spruce beetle infestations may help to prevent some additional damage. But few, if any, methods have proven successful in turning the course of an outbreak. Although the long-term aim should be to encourage healthy, vigorously growing stands that are maintained in a condition of relatively low risk of attack by beetles, sometimes beetle populations may build up in response to events that create a large supply of favored food (such as windthrow or large logging residues) and threaten otherwise healthy, thrifty stands.

From the prevention side, several measures can be taken to ensure that the probability of loss of trees and stands to spruce beetle are minimized. While there is no absolute way to guarantee spruce beetles would not become a problem in stands in the future, careful attention to the practices outlined below will go a long way toward avoiding spruce beetle problems:

Planning and Silvicultural Stand Treatment (adapted from Safranyik 1981, and other sources as indicated):

- Assign management priorities to stands or areas. Management objectives should dictate the level or need for spruce beetle management. Use the stand risk rating system to help identify the relative susceptibility of stands to spruce beetle, and utilize both annual aerial survey information and ground survey data to identify potential problem areas (blowdowns, spruce beetle activity, etc.).

- Plan harvesting of susceptible stands in high-priority areas. Utilize Alexander's (1987) guidelines, and direct harvesting at the most susceptible stands.

- Grow spruce on a short rotation (100 years or less), or harvest stands before trees become too large and growth declines. Where this is not possible, and in older stands, use stocking control to reduce competition and encourage tree growth, but don't open stands so much that stands are exposed to possible windthrow. Windfirmness is an important consideration in planning for entries in spruce stands. Alexander (1987) provides some guidelines regarding the relative risks of windfall for various exposures.

- Develop a mosaic of age classes and/or mixed stands. Utilize lodgepole pine, western larch, subalpine fir, and other species appropriate for the site. Engelmann spruce can be managed on an even-aged basis as long as shelter is provided or windrisk is small. This may be desirable under shortened rotations.

- Routinely fall conventional trap trees each year in spruce harvesting areas to continually reduce the spruce beetle populations (Hodgkinson 1985). Trap trees can be deployed as patches, decks, strips, and/or pre-felled landings and rights-of-way. Once the traps become infested, they *must* be removed or otherwise treated before the brood matures to attack new hosts.

- If spruce beetle populations are increasing in high-value areas where cutting large spruce may be undesirable (such as campgrounds), utilize protective sprays (carbaryl, lindane, or chlorpyrifos) on boles of trees to prevent tree killing by the beetles.

- Maintain vigor of high value spruce in campgrounds and administrative sites by adequate watering during dry periods, by light applications of fertilizer at intervals of 1 to several years, and by spacing trees to reduce competition for soil moisture (Hard and Holsten 1985).

Windfall and Slash Management (adapted from Safranyik 1981, and other sources as indicated):

- Promptly salvage wind-thrown trees.

- Control cutting boundary layout to avoid situations that increase the probability of blowdown (utilize guidelines by Alexander (1987) to minimize windrisk).

- Adhere to close utilization standards. Trees should be cut as low to the ground as possible to reduce stump height, preferably less than 1.5 ft. If logs are logged full length, then the diameter of the small end should be 3 to 4 in. (Schmid 1977).

- Practice post-harvest cleanup of stands by treating large-diameter slash, stumps, and landings where large residues accumulate. Cull logs and tops should be limbed and the branches kept away from the bark surface of the bole. After limbing, the cull logs and tops should not be piled but positioned away from any shade. Logs and tops should be cut into short lengths, the shorter the better, to help speed drying of the cambium (Schmid 1977). Infested pieces should be treated by solar heat, with chemicals, or burned (Holsten et al. 1989). Peeling of infested pieces will expose the immature brood to the elements. It is not necessary to peel the entire bark; strips an axe-blade wide, at 3 to 4 inch intervals around the log, would be sufficient (Fiddick 1978).

- Avoid extensive soil disturbance near stand edges. Displacement of roots can make trees more prone to windthrow and soil compaction and root damage can stress trees, making them more susceptible to beetle attack.

- Should a spruce beetle infestation become incipient, initiate prompt action to salvage or log the area, and utilize trap trees.

- Employ trap trees to absorb and contain building spruce beetle populations. Use guidelines provided by Hodgkinson (1985), and Scott (1990).

- Use aggregation pheromones with trap trees to enhance their attractiveness. The antiaggregative pheromone, MCH (3-methyl-2-cyclohenen-1-one) may have some promise as a repellent for spruce beetle, however it is not yet registered with the EPA, and can only be used with limitations, under an Experimental Use Permit.

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Fir Engraver (Scolytus ventralis LeConte)

Hosts and Community

The fir engraver is the most important bark beetle on true firs in the Blue Mountains. It attacks and kills trees of nearly all age classes, from pole size to mature sawtimber. It also readily attacks windfall firs and green cull logs resulting from logging operations, especially those that are sheltered from direct sunlight (Struble 1957). Fir engravers are most destructive to white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.), and grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.) throughout the host range of these conifers. In addition to these, Hopping (1922) lists California red fir (*Abies magnifica* A. Murr.), and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) as hosts for the fir engraver. Struble (1957) and Chamberlin (1958) added subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), and mountain hemlock (*Tsuga heterophylla* (Raf.) Sarg.) to the host list for fir engraver. Ashraf and Berryman (1969) expanded the host list further when they reported observing fir engraver attacking western larch (*Larix occidentalis* Nutt.). California red fir is the only fir engraver host species that does not occur in the Blue Mountains. Of the conifer hosts that occur in the Blue Mountains, usually only white fir and grand fir, and to a much lesser extent, subalpine fir, are attacked and killed in numbers large enough to be of consequence to resource management. Fir engravers have only rarely been observed to kill the other hosts listed. Though the engravers are more likely to attack these trees when large numbers of them infest grand fir or white fir stands with the other hosts intermingled or when the hosts have already been attacked by other bark beetles.

Host tree species of the fir engraver range throughout much of the Blue Mountains physiographic province. True firs and Engelmann spruce occur as both overstory and understory shade-tolerant stand components, while western larch is a shade-intolerant seral component of various plant associations. Douglas-fir is more tolerant of shade than other seral species, and is found both as an overstory and understory stand component in many stands throughout the area. Vegetation series where fir engravers occur range from the cool, moist mountain hemlock series (CM), subalpine fir series (CE/CL), and grand fir series (CW), to warmer and drier pine sites that have been invaded by true firs.

Grand fir occurs as either a climax or seral species, ranging from a late colonizer of dry forest sites to a pioneer on burns or clearcuts (Hall 1981). In the Blue Mountains, periodic underburning historically maintained ponderosa pine and some Douglas-fir on sites that also contained pinegrass (*Calamagrostis rubescens* Buckl.) and ceanothus (*Ceanothus velutinus* Dougl. ex Hook.), as well (Hall 1981). As a result of fire suppression activities, grand fir now commonly occupies these sites. Stands of grand and white fir typically become overstocked and stagnated, creating ideal habitat for fir engraver and other defoliators such as Douglas-fir tussock moth (*Orgyia pseudotsugata* (McDunnough)), and western spruce budworm (*Choristoneura occidentalis* Freeman).

Biology

The fir engraver is a native bark beetle species. The adults and developing broods of the fir engraver kill their host by mining in the cambium, phloem, and outer sapwood of the bole, effectively disrupting flow of water to the crown by girdling the tree. In addition, their tree killing activity is aided by a fungus introduced by the beetles. Wright (1935) first described the inoculation of trees with a brown staining fungus, *Trichosporium symbioticum* Wright, which is carried in mycangial pits on the beetles' heads and introduced by them as they attack the tree (Livingston and Berryman 1972). The fungus hastens death of the tree by plugging the water and nutrient transport system of the inner phloem. The fungus stains the sapwood surrounding the etched gallery that is the characteristic signature of the fir engraver. The fungus also stains the cambium and causes it to dry out (Struble 1957).

Fir engravers produce one generation per year, each of which requires about a year to complete development. Adult beetles, which emerge from trees infested the previous summer, fly in search of new hosts from June to September. First flight begins about mid-June and continues into late September, with beetle flight peaking around mid-July. Daily flight patterns of beetles vary with air temperature, but most flight activity occurs between 1400 and 1700 hrs, when ambient air temperatures are normally above the beetles' flight temperature threshold of 24°C (Ferrell 1971).

After attack, females construct a nuptial chamber and are soon joined by a male, and mating takes place. Egg galleries are constructed in a horizontal direction across the grain on both sides of the nuptial chamber by the female beetle. Tiny niches are prepared in the lateral walls of the gallery, on both the upper and lower gallery surfaces, and individual eggs are laid in each niche. A female will lay between 100 and 300 eggs in the average completed gallery (Struble 1957). After egg deposition, the female backs into the entrance hole and soon dies, thereby blocking the entrance hole and possibly preventing the entry of natural enemies (Struble 1957). Eggs hatch within 2 weeks, and the larvae feed by mining vertically away from the egg gallery within the cambium-sapwood interface, scoring the sapwood as they advance. Larvae develop through six instars, a process requiring about 2 months under room conditions (Scott and Berryman 1971). Development time under field conditions can vary widely, and is dependent upon temperatures which either stimulate feeding or cause dormancy (Struble 1957). In addition, Struble (1957) reported that the maximum period for fir engraver larval development was found to be 380 days at 7,500 feet elevation, and the minimum period was 41 days at 3,500 feet. Fir engravers overwinter primarily as young and mature larvae, but pupal and adult stages may be present as well. The larvae cease to feed as the temperatures decline during winter and they remain dormant until temperatures rise again in the spring and summer, at which time they resume feeding and complete development.

The sixth instar enters a quiescent nonfeeding prepupal stage before molting to the pupa at the end of the larval mine (Berryman and Ferrell 1988; Struble 1957). The pupal chamber is most commonly constructed in the inner bark, but may be found at any point from immediately beneath the sapwood surface to the outer bark (Struble 1957). Pupation lasts from 10 to 14 days.

Adults emerge by boring through to the surface of the bark. Multiple, small, round exit holes, about 2 mm wide (slightly smaller than the diameter of a pencil lead) are apparent and scattered over the bark surface after emergence of adult beetles. Attack holes are usually more difficult to see because they are often located in the bark crevices and fissures where the bark surface is roughened.

Host selection by female beetles is said by some to occur at random (Berryman and Ferrell 1988), but Coulson and Witter (1984) state that colonization is guided by host attractants and insect-produced pheromones. Apparently, both types of selection processes are used by tree-killing *Scolytus* spp. (Wood 1982). Though the aggregation pheromone used by the fir engraver to concentrate populations of beetles on the trees in numbers large enough to overcome host resistance has not been identified, such pheromones have been isolated and identified in other species of *Scolytus* (Pearce et. al. 1975).

Initiation of colonization attacks may occur on the bole or on larger limbs and tops of host trees. Beetles have been noted attacking both resistant and susceptible firs, but evidence also exists to show that they abandon entrance holes made during the attack on certain resistant trees. In such cases healthy, vigorous host trees have the ability to resist beetle attacks: Either by utilizing their pre-formed resin system of canals and pockets in the cortex of the bark, or by a dynamic induced response (hypersensitive reaction) in which resin infuses tissues containing the egg gallery, killing the brood, and producing a resinosis and death of phloem tissue and the formation of traumatic resin cavities in the outer sapwood at the edge of the lesion area (Berryman and Ferrell 1988). Trees that have been attacked by beetles sometimes exude streams of clear pitch down the bole from beetle entrance holes (Ferrell 1986). This occurs most commonly near the upper portion of the bole, and sometimes the pitch flow may be heavy enough to drown the beetles or cause them to abandon their entrance holes (Ferrell 1986).

Fir engravers have the unusual ability to establish egg galleries without causing the death of its host (Ferrell 1973a; Ferrell 1974; Struble 1957). The cambium is typically killed at those locations where limited attacks occur, but the tree survives. These types of attacks are generally referred to as "strip" or "patch" attacks, depending on the size, shape, and arrangement of the attacks along the bole. In some cases, adult females are able to construct a gallery, lay eggs, and even have them hatch, before death of the brood occurs by resinosis, as described above. Many times, however, broods are successful and development proceeds to the adult stage. These wound areas eventually heal in time, as the cambium gradually grows over the lesion. Eventually, these attacks become buried deeply in the wood as the tree continues to grow radially. Numerous scars resulting from fir engraver attacks are sometimes evident in cross-sections of mature trees; they appear as deeply stained annual rings. Most trees that have been examined containing these healed-over fir engraver-caused wounds have been found to exhibit a column of wood decay many years later, that may extend over an area of a square foot or two at the site of the wound (unpublished observations by D. Scott and C. Schmitt, 1990). The rate of decay formation is unknown but appears to require several years to become expressed. Decay seems to show up 10 to 15 or more years following attack, and sometimes extends an inch or two into the sapwood from the area of the lesion. These healed over wounds appear as roughened patches of bark, and oftentimes, beneath the bark surface, a brown pitch pocket may form where the cambium healed over (Ferrell 1986).

Most of the initial beetle attacks on a tree occur in the crown. These attacks may occur all around the bole near the top so that they often girdle the top which appears many months later as a "red top." Other attacks may occur at the point that a branch enters the trunk. Galleries at these locations girdle the branch, disrupting the flow of water and nutrients and killing the branch (Ferrell 1986). These dead branches eventually fade to a reddish brown color and are commonly called "flagging." Mass attacks all along the bole of the tree will kill the tree and the entire crown will fade within 3 to 6 months of the attack. Attacks are usually confined to portions of the trunk larger than 4 inches in diameter, and are heaviest in the upper third to half of the trunk, but they may extend almost to ground level (Struble 1957).

History

The fir engraver is a bark beetle that has, within the last decade or two, assumed greater importance in the scheme of modern-day resource management than it had 50 or more years ago. This insect normally maintains a sizeable part of its population in living trees, widely scattered throughout the grand fir and white fir host types. The fir engraver's ability to kill individual branches or tops, while not killing the tree has contributed to the success of this beetle in exploiting its host. Not only can it repeatedly attack portions of tree crowns year after year without exhausting or killing its food source, it is able to maintain viable populations sufficient to kill trees when they become weakened and susceptible through various catastrophic events (e.g. defoliator outbreaks and drought). Trees gradually weakened by repeated crown attacks over a number of years may eventually be mass attacked and killed by fir engravers and/or woodboring beetle species commonly found working in conjunction with fir engravers (or killing trees independent of fir engravers). A roundheaded woodborer, the roundheaded fir borer (*Tetropium abietis* Fall), is an important factor in killing old and mature trees (Struble 1957); while a flatheaded woodborer, the flatheaded fir borer (*Melanophila drummondi* (Kirby)), kills trees from pole-size on up; especially those growing on dry sites or during droughty years (Scott 1978).

When gathered from among a number of proximal stands, fir engravers readily amass tree-killing populations of beetles large enough to kill small groups of trees, especially during periods of drought and severe defoliation by western spruce budworm or Douglas-fir tussock moth. From such an initial situation, beetle populations build rapidly within a few years as stands continue to be weakened by defoliation or drought, so that many more scattered pockets of trees are killed, with trees in the groups sometimes numbering in the hundreds. Thus, fir engravers, at times, can cause high mortality of host trees. These factors are historically linked to some former fir engraver outbreaks in the Blue Mountains, as well as to the current outbreak.

In past decades, true firs were considered of little economic value, and because of this and the fact that it was too difficult to treat individual trees or small widely scattered infestations, much of the fir engraver activities of the past were probably not considered serious enough to warrant concern. Today, however, true fir is relatively more highly valued in some commodity markets, and its benefits as a cover species for big game wildlife are indisputable.

There is no recognizable pattern of fir engraver outbreaks; they characteristically appear to occur at irregular intervals. When outbreaks do occur, however, their simultaneous occurrence in many widely separated localities, causes severe damage to forests (Struble 1957). According to Struble (1957), sporadic outbreaks have been recorded in California and Oregon at least once a decade since 1925. The enormity of damage from these fir engraver outbreaks is mind-boggling with the average annual loss (during outbreak) in California alone estimated at 450 million board-feet.

Fir engraver outbreak records for the Blue Mountains are not very well documented. The historical records that were reviewed regarding fir engraver date from 1937. Documents that discuss fir engraver trends in the Blue Mountains prior to 1937, if such documents exist, have not been examined. The years 1938 and 1939 were marked by heavy killing of grand fir by fir engravers, most of which occurred on the Wallowa and Whitman National Forests. The cause of this outbreak is unknown. The Fairchild Lookout area on the Wallowa National Forest lost 10 to 15 percent of the grand fir in stands due to fir engraver in the years from 1937 to 1939. The infestation subsided in 1940, however. Elsewhere, fir engraver-caused tree losses were normal to somewhat below normal during this period (USDA 1946).

The fir engraver remained at low levels for a number of years following the 1937-39 outbreak. Populations increased slightly during the early 1960's, mostly on the Umatilla and Wallowa-Whitman National Forests (Fig. II-15). Precipitation records indicate lower than normal moisture at several locations in the Blue Mountains during 1961-62, especially. Therefore, droughty conditions were likely the cause of increased beetle activity during the early 1960's. Much of the tree mortality occurred in overmature trees and low value stands at high elevations, but some vigorous young stands were reported to have been damaged by fir engraver as well (Orr and Pettinger 1964).

Populations of fir engraver increased over significant areas of the Blue Mountains, particularly on the Umatilla and Wallowa-Whitman National Forests during the late 1960's and early 1970's (Fig. II-15). The outbreak had trailed off by 1972, but the Douglas-fir tussock moth outbreak during the early to mid-1970's fueled an increase in fir engraver beetle activity again. Wright et. al. (1984) found that the beetle activity, measured in total number of beetle attacks on trees, peaked 1 to 2 years after defoliation ended, and then declined. They also found trees with greater than 90 percent defoliation were most likely to be infested by beetles during the outbreak period.

The fir engraver outbreak that occurred as a result of tussock moth defoliation in true fir stands declined by 1977. Following this outbreak, beetle activity remained at relatively low levels for the next decade. An outbreak of western spruce budworm which started in 1980, exacerbated by several years of drought, ignited another fir engraver outbreak which began in 1987. This outbreak increased rapidly for two years before it began to drop slightly last year (Fig. II-15). This current outbreak, although apparently beginning to decline, will likely continue to cause a significant amount of tree mortality for several more years.

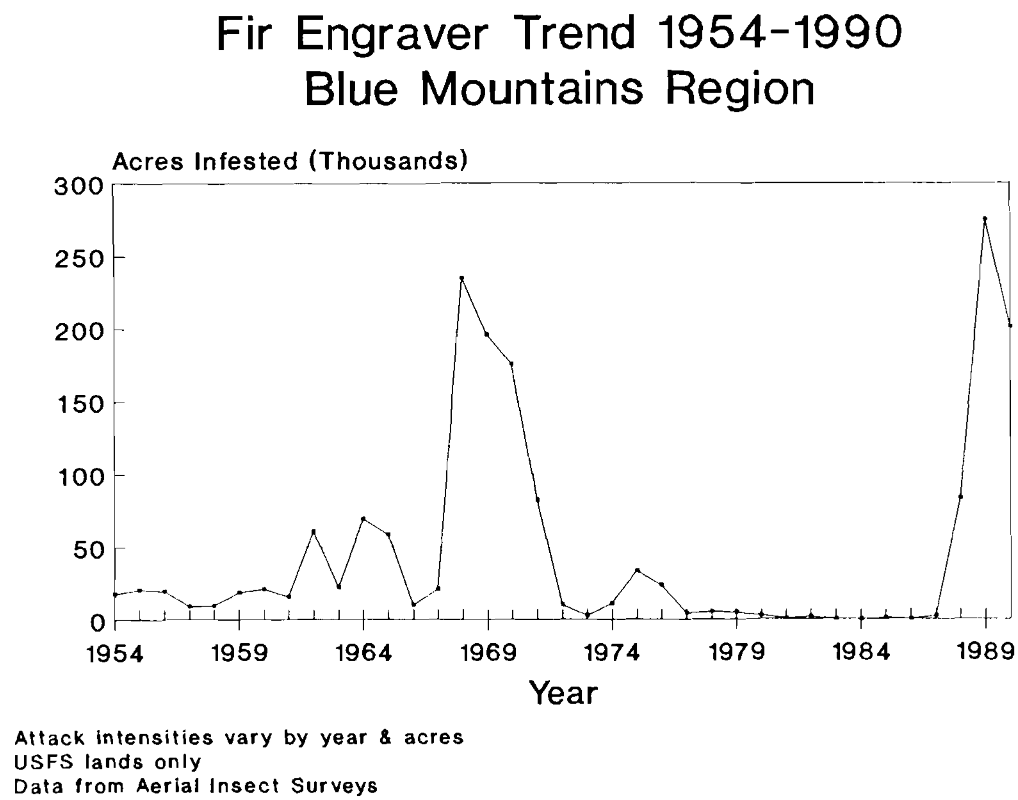


Figure II-15
Fir engraver infestation trend from 1954 thru 1990 on National Forest lands (Malheur, Umatilla, and Wallowa-Whitman) in the Blue Mountains. (Based upon Aerial Insect Detection Survey data)

Stand Conditions

Fir engraver populations are maintained at endemic levels by the top-killing and branch-killing mechanisms described above, as well as by the annual tree killing of a few unhealthy trees whose vigor has been reduced by age, competition, disease, and other factors (Berryman and Ferrell 1988). Sometimes individual old trees in mature stands, even though appearing to have adequate spacing between them and neighboring trees, are sometimes attacked and killed by fir engraver beetles. But trees that are killed in groups are more often found in younger and second-growth stands with trees growing in closer association to one another, leading to the conclusion that competition may be the factor most responsible for this type of group mortality.

Dry sites, drought, and root disease also play especially important roles in the susceptibility of true fir species to fir engraver, and they are probably the most important factors influencing the food supply for beetles. Existence of abundant habitat allows fir engravers to rapidly expand populations to outbreak levels. Under normal moisture conditions, overstocking of fir stands and high infection rates by root disease are the principal factors involved in predisposing trees to attack by fir engravers.

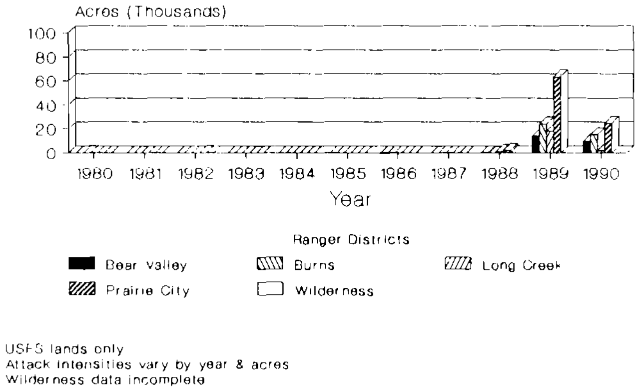
The close association of attack by fir engravers and incidence of root disease in fir engraver host trees is well documented. Lane and Goheen (1979) found that nearly 86 percent of recently beetle-infested trees (examined in their investigation of bark beetle-root disease interactions on the eastern slope of the Cascade Mountains in Washington and Oregon) had advanced cases of root disease--principally Armillaria and laminated root disease. A similar investigation has not been conducted in the Blue Mountains, but observations show that the association between fir engraver attacks and root diseased trees is probably comparable to the values reported by Lane and Goheen. The main difference, however, is that fir engraver attacks in the Blue Mountains are associated with trees containing Annosus root disease and Armillaria root disease, rather than laminated and Armillaria root diseases. Likely, this is due to the fact that there is significantly less laminated root disease occurrence in the Blue Mountains than in the Cascades or coastal mountain ranges. Hertert et. al. (1975), and Miller and Partridge (1974), found the interaction of bark beetles and root-rot pathogens in grand fir in Idaho to be even higher than those reported for Oregon and Washington by Lane and Goheen (1979). Hertert et. al. reported that 96 percent of the trees attacked by bark beetles also had root rot; Miller and Partridge found a 98 percent association. These data also suggested that bark beetles most often invaded hosts after infection by root disease. But in any case, there is no question that root disease appears to be an important factor in predisposing fir to attack by bark beetles.

A rapid buildup of fir engraver populations to epidemic levels is indicative of other conditions which promote substantial increases in food supplies, such as can occur when large numbers of host trees are weakened by catastrophic events (defoliation, drought, and others) (Berryman and Ferrell 1988). The lowering of tree resistance enables beetles to successfully attack and breed in host trees. Factors that tend to uniformly affect tree vigor over large areas predispose trees to beetle attack. Two of the principal events--term them catastrophic because they occur rapidly and affect very large areas--that have led to some past fir engraver epidemics in the Blue Mountains are defoliating insect outbreaks (Douglas-fir tussock moth and western spruce budworm), and prolonged drought. Minor discussions of both these factors were given in the History section above. However, regarding drought, it is worth noting that in California and southern Oregon, some past outbreaks were associated with subnormal precipitation for 2 or more years preceding the outbreak (Struble 1957). We know from our experience with tussock moth and budworm epidemics in the Blue Mountains that a similar delay in bark beetle buildup occurs following defoliator outbreaks. The ability of the current budworm outbreak to predispose hosts to bark beetles has been increased considerably due to four or five years of additional weakening by drought: Yet, we have also observed many areas where grand fir or white fir have been killed by fir engraver, with little evidence of defoliators, and no root disease present. Undoubtedly, drought alone, or in conjunction with tree competition resulting from lack of stocking control, has been responsible for this beetle-caused mortality. Ferrell (1986) cites other examples of fir engraver outbreaks that coincided with periods of drought. Because it lowers the natural resistance and vigor of trees, drought is unmistakably one of the most critical factors in determining outbreaks of fir engraver. When moisture conditions return to normal, fir engraver epidemics rapidly subside.

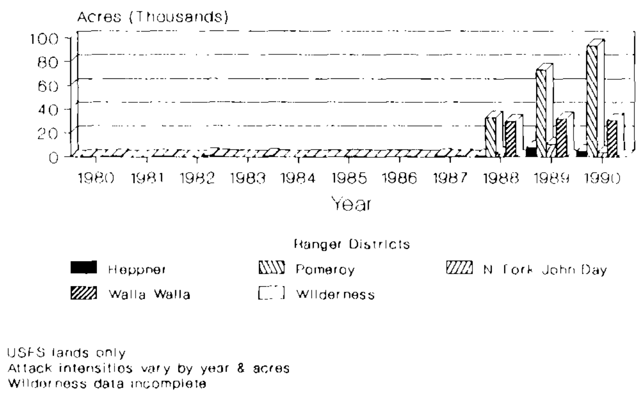
Occurrence

Occurrences of fir engraver populations on the Malheur, Umatilla, and Wallowa-Whitman National Forests (Fig. II-16) were extremely low for the first 7 or 8 years of the past decade (i.e., 1980-1987). The western spruce budworm outbreak in the Blue Mountains, which began in 1980, peaked by about 1986 on most Ranger Districts and began declining thereafter. The increase in fir engraver activity on three National Forests in the Blue Mountains followed the decline in budworm populations and began increasing in about 1988, two years after peak of defoliation by budworm over most areas. This beginning of the fir engraver outbreak also trailed the beginning of the drought by about 2 years. This pattern is similar to that reported for fir engraver in the past (Ferrell 1986; Struble 1957).

Fir Engraver Infested Acres
Malheur National Forest



Fir Engraver Infested Acres
Umatilla National Forest



Fir Engraver Infested Acres
Wallowa-Whitman National Forest

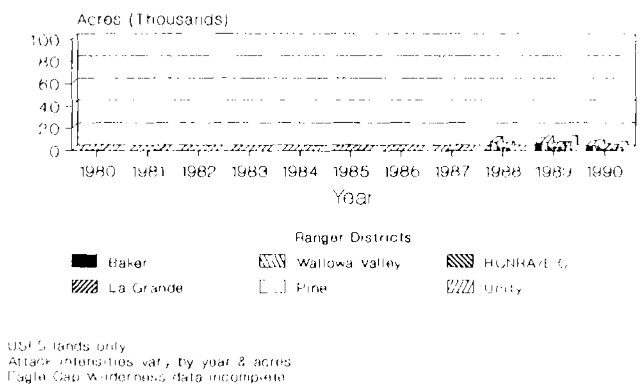


Figure II-16
Acres with visible fir engraver-caused tree mortality on National Forests in the Blue Mountains from 1980 thru 1990. (Based upon Aerial Insect Detection Survey data)

The number of acres infested by fir engraver seems to have peaked in 1989 on the Malheur National Forest (Fig. II-16). It is not certain that the decline in infested acres seen in all Ranger Districts on the Forest in 1990 will continue into 1991. The reason for this is the resurgence of budworm on the Forest, and the possibility of increasing tussock moth populations which could lead to another outbreak within a year or two. Another factor may be the drought, if it continues to prevail during 1991 and beyond, it will continue to foster conditions conducive to fir engraver outbreak.

The Umatilla National Forest has been continuing to experience increasing acres of infestation by fir engraver beetles over the past three years. Budworm has also resurged in numerous areas of the Forest and may continue to weaken fir trees, thereby making them susceptible to fir engraver beetles. The greatest increases in engraver-infested acres is occurring on the Pomeroy Ranger District (Fig. II-16), but it is probably related more to drought-stress and root disease occurrence than to budworm defoliation, since budworm defoliation has been relatively low for four or five years on that District. Other Ranger Districts on the Umatilla appear to be either holding steady, or declining slightly with respect to the number of acres infested by fir engraver.

Compared to the other two National Forests in the Blue Mountains, fir engraver activity on the Wallowa-Whitman National Forest increased only slightly between 1987 and 1988, and has remained stable and relatively low up to the present. This may be due in part to the extremely aggressive salvage program conducted by the La Grande District in the wake of the western spruce budworm epidemic, which was most damaging to the district's mixed conifer stands. However, the amount of acres infested by fir engraver on the Wallowa-Whitman National Forest could increase within the next three to five years due to weakening of fir engraver host trees by tussock moth defoliation.

Suppression

Suppression efforts directed against fir engraver are rarely recommended, required, or conducted. In order for suppression to be effective, a high percentage of the beetle population must be found and wiped out (Struble 1957). This task would be extremely difficult, if not impossible to accomplish because a large portion--perhaps half or more--of the beetle population is maintained in individual, partially infested, widely separated trees scattered throughout the forest. These trees are hard to spot, except by thorough, intensive ground searches. Moreover, trees that have been topkilled, patch, or strip attacked, quickly recover, and the generation of beetles produced moves on to attack other trees after emergence the following summer.

Trees that are killed could be removed before beetle emergence, but a significant proportion of the total beetle population would likely remain in the partially-infested trees. Thus, Struble (1957) points out that "controlling the beetles in dead trees and ignoring those in the others is not sound practice; therefore, direct control is generally not practicable."

It would be hard to imagine a situation in which the loss of the engraver infested true firs balance evenly against the effort and expense required to seek out all partially-infested and beetle-killed trees and remove them from the woods or fell them and destroy the fir engraver broods. Nevertheless, it is possible to accomplish destruction of fir engraver broods. Ferrell (1986) lists several ways of accomplishing this in individual trees. These include the following:

- The infested tree can be felled and the bark burned in place or the bark peeled and then burned.

- The infested tree can be felled, limbed, and left fully exposed to the sun, provided the logs are rolled every few days to expose all parts of the bark.

- o The infested tree or log can be submerged in water for at least 6 weeks.
- o The infested tree can be felled, and the trunk sprayed with insecticide using a low-pressure sprayer.

Additional details regarding the use of the direct control methods above can be found in Struble's (1957) publication.

The use of chemical insecticides to kill fir engraver brood developing beneath the bark has been effective in some instances. Some of the compounds that were used in the past were not registered with the U.S. Environmental Protection Agency (EPA), or their registration has been suspended for various reasons. Compounds such as ethylene dibromide (EDB) and orthodichlorobenzene diluted with fuel oil were very effective in controlling beetles in both infested logs and standing trees. Of these two insecticides, only EDB was registered for this use (Hamel 1983), but has since been suspended from use by EPA (USEPA 1990). Currently, endosulfan is the only registered insecticide for control of fir engraver in infested logs (Hamel 1983). It is applied as a ground spray to felled logs in late spring.

Effects

The impacts and effects of fir engravers on managed resources on state, private, or Federally administered forest lands are not very well documented. As one would imagine, the impacts on the timber resource are best known. Acreage infested, and even volume estimates, could be made regarding losses of timber by fir engraver. Indeed, figures were cited earlier for some average annual losses of timber to fir engraver in California. It is also established (Ashraf and Berryman 1969; Struble 1957) that in addition to direct volume losses from fir engraver-caused tree mortality, many trees that survive repeated sublethal attacks develop defects and rots which render them undesirable for manufacture into lumber and wood products. Deterioration and defects, indirectly caused by fir engraver attacks, influence wood quality and are of significance in lumber manufacture (Ashraf and Berryman 1969).

White and grand firs are also important on many watersheds and recreation areas (Berryman and Ferrell 1988), but the extent to which these resources may be affected by fir engraver beetles remains to be discovered. Undoubtedly, the impact will vary considerably, both spatially and in relation to the degree to which true fir stands are involved in the management of these resources. The best and most current information available in the Blue Mountains comes from the survey conducted on Ranger Districts of the Malheur, Umatilla, and Wallowa-Whitman National Forests, as part of this Forest Health Project.

Based on this survey, viewsheds and wildlife resources were indicated as being the management allocations impacted the most, in terms of acres, by fir engravers. And the impact intensities for the majority of acres in these areas were considered to be in the medium and high ranges. Most other resources or management allocations, including wilderness, special, riparian, old-growth, and timber, exhibited only low or medium intensity impacts from fir engravers: And the proportion of acres in these management allocations being impacted was relatively low. In certain stands within these allocations, it is probable that western spruce budworm may be additionally affecting the resource, and the weakening of trees by defoliation is probably responsible for encouraging fir engraver-caused losses. Other stands are probably being more strongly influenced by drought than budworm defoliation as a predisposing factor to bark beetle attack.

It is not clear how Ranger Districts view fir engravers as impacting the resources they are managing, but it is likely that epidemics of fir engraver are causing such significant losses that wildlife cover and continuity of canopy are disrupted to the degree that detrimental effects on wildlife populations and visual resources are occurring. More detailed investigations may help reveal specific ways resources and management allocations are being affected by fir engravers in the Blue Mountains.

The perception of the general public, as well as those engaged in commercial enterprises in conjunction with forest lands, may further illuminate this question. Permittees and operators of concessions such as ski areas may have greater concern about the impacts of fir engraver on the stands within and adjacent to the areas in which they operate. The possibility of damage to their facilities and equipment, or injuries to their clients, brings light to important liability questions. With the close association of fir engravers and root-rotted trees, a high probability exists for some form of failure to occur in certain trees, which the beetles may actually be useful in pointing out. Therefore, they could act to indicate potential problem areas that should be investigated further.

Hazard Rating

Hazard-rating (or risk-rating) systems have been developed for fir engraver for red fir and white fir stands in northern California (Ferrell 1980; Ferrell 1989) and for grand fir stands in northern Idaho (Moore et. al. 1978; Schenk et. al. 1977).

The background for development of the northern Idaho method can be traced to the work by Ferrell (1973b), in which he investigated the interrelationships between fir engraver attack "scar" density and site quality, dbh, height, age, volume, and growth rate in white fir: The association of fir engraver- and roundheaded fir borer-caused white fir mortality with tree growth and weather factors (Ferrell and Hall 1975) was also studied.

Based on the relationship of beetle attack to stand condition and species composition of stands, Schenk et. al. (1977) developed a stand hazard rating system (SHR) for stand susceptibility to fir engraver--using stand density and host tree availability as predictor variables. Stand density was measured by Crown Competition Factor (CCF) (Krajicek et. al. 1961), and host availability was determined by a modification of the Diversity Index (DI) (Brillouin 1962; see Schenk et. al. (1977) for modification). When the SHR was used to rate grand fir stands in northern Idaho for engraver-induced tree mortality, the index of stand hazard showed a strong correlation with the number of trees killed by the fir engraver during a 3-year period. The stand hazard index was made even more useful to resource managers by altering it to allow mortality to be expressed in terms of proportion of grand fir killed per acre, though a slight decrease in the predictive capability did result (Schenk et. al. 1977).

The drawbacks of the stand hazard rating system by Schenk et. al. (1977) are twofold: First, the preliminary model was intended for use only in grand fir dominated stands with an average stand dbh greater than 6 inches. Since stands included in the sample data set used to develop the stand hazard rating index were only those in which the weighted value for grand fir (used in the equation for calculating DI) was numerically larger than that for any other individual species, the stand hazard rating system is biased towards those stands which have grand fir as the dominant species component. The model has been validated and refined for a range of densities and tree species composition conditions (Moore et. al. 1978), but in all cases, grand fir was dominant in the stands. Therefore, it is not known whether the model would be valid in stands in which grand fir were a minor species component. Secondly, development of the model ignored the relationship between fir engraver and root-diseased trees. With the very high correlation of fir engraver attacks on trees with root rot, it is likely that incidence of root disease would have a profound effect on stand susceptibility to fir engravers, and yet this was not evaluated during the development of the stand hazard rating system by Schenk et. al. (1977).

The risk-rating systems developed by Ferrell (1980) are a modification of the California Risk-Rating System that was developed for determining trees' susceptibility to western pine beetle, *Dendroctonus* *brevicomis* (Smith et. al. 1981). The principle of utilizing an awards/penalty point system of assigning risk based on an analysis of the crown and bole characteristics of trees, has been adapted by Ferrell for mature red fir and white fir in northern California. Ferrell's approach to risk rating white fir is to estimate the Percentage of Crown with branches oriented horizontally or upswept (Branch Angle Percent), Crown Density, Percent Crown Raggedness (Ragged Percent = percent of crown missing, dead, or dying), and whether living inner bark was visible in bark crevices at breast height (Bark Fissures). Using these predictor variables, Ferrell developed regression equations in the form of logistics functions, to predict the probability of a tree's death within 1 year. These probabilities were extrapolated to probabilities of death within 5 years by using a modification of a standard compound interest formula. The risk equations that were developed were directly translated into Award-Penalty Point Systems in which trees are awarded points on the basis of predictors with positive regression coefficients, and penalized points on the basis of predictors with negative coefficients (Ferrell 1980). However, it should be noted that this system, though it is fairly straight-forward, is somewhat subjective, and is applicable only to mature trees, at least 10 inches in dbh.

Additional work on the risk-rating systems for red fir and white fir in California, has led to development of an Award-Penalty Point System that allows estimation of risk of fir engraver attack in trees down to 4 inches dbh growing in stands with a wide variety of size and age structure in northern California (Ferrell 1989). This system also allows predicting the probability that a tree will die from natural causes--insects, diseases, intertree competition, etc.--within a 10-year period. Ferrell (1989) suggests that the system, though developed for northern California can be tentatively used outside this region, pending studies to test it in other areas. Although it is not directly used in the determination of susceptibility to beetle attacks in the risk-rating system, Ferrell (1989) did take into account tree disease occurrence (whether responsible for beetle attack or not) in his risk-rating system's predictions of mortality.

Past use of either of these stand hazard-rating (or tree risk-rating) systems in the Blue Mountains for susceptibility to fir engraver, could not be verified. It is doubtful whether they have been tried, but their use by resource managers would by beneficial in many ways to the management of stands and associated resources in the Blue Mountains. For example, the risk-rating system could be used as an aid in developing marking guidelines for creation of habitat for cavity-nesting birds, or the stand hazard-rating system would be helpful in prioritizing stands for silvicultural treatments, but such possibilities have probably not been explored by resource managers in the Blue Mountains.

Models

Computer-based modeling systems for simulating rate of tree loss to fir engraver, and fir engraver population dynamics, have not yet been developed to any degree. The stand hazard-rating system developed by Schenk et. al. (1977), however, offers a good possibility for development of a rate-of-loss model for fir engraver. This could be linked to the stand growth and yield simulation model PROGNOSIS (Stage 1973), and used to project the effects of periodic fir engraver epidemics on stand volume through time. The stand hazard-rating system for fir engraver could also help to identify those stands most likely to sustain epidemic infestations of fir engraver (Schenk et. al. 1977).

Linking the fir engraver stand hazard-rating model to PROGNOSIS would offer the possibility of evaluating the affects of alternative management regimes, conditioned on the probability of fir engraver outbreaks (Schenk et. al. 1977). The opportunity of using such a PROGNOSIS-linked pest model for fir engraver would broaden the spectrum of analytical methods available to the resource managers. Carried to its ultimate development, cross-linkage to other pest models would permit analysis of multiple-pest interactions such as the influence of tussock moth or budworm defoliation, or root disease occurrence, on fir engraver activity. Thus, future development of models to simulate analysis of multiple-pest interactions such as the influence of tussock moth or budworm defoliation, or root disease occurrence, on fir engraver activity. Thus, future development of models to simulate population dynamics and beetle-related impacts on timber volume and various other resources, would greatly benefit resource management in the Blue Mountains, and should be encouraged.

Management

Management of stands to minimize fir engraver-caused losses and damage from fir engraver is generally approached from the strategy of prevention, rather than suppression. In an earlier section (see Suppression) it was noted that direct control or suppression measures are impractical and generally not recommended for fir engraver. This bark beetle's ability to infest host species without killing them makes locating and eliminating broods difficult or impossible. Therefore, management of fir engraver can only effectively be accomplished through silvicultural means. Struble (1957) suggests that removal of decadent and weakened firs, thereby improving the growth and vigor of the remaining stand, offers the best possibilities for minimizing fir engraver damage. Ferrell (1986) likewise promotes these actions, but also adds that diseased and injured trees should be removed, and overly dense stands should be thinned to reduce tree competition. In addition, since fir engraver populations readily attack windthrown trees and cut logs, Ferrell (1986) further recommends that they be removed within a year, before beetles can produce new broods.

In conducting management activities to improve and maintain tree and stand health and vigor, it is important to utilize methods and frequencies of stand entry which are designed to reduce compaction of soils, and prevent excessive tree-exposure (Johnsey 1984). One of the most important factors in managing fir engraver problems is recognition and management of root disease problems in stands. A root disease-infected stand experiences significantly reduced vigor and natural resistance, and trees are predisposed to attack by fir engraver beetles. If disease problems are adequately addressed in silvicultural prescriptions for stand treatment (and in marking plans), the treatment of the disease will normally resolve the fir engraver problem as well. Since some ground-disturbing activities can exacerbate root disease problems (see section, Important Forest Diseases in the Blue Mountains), the planned frequency and nature of entries for harvesting and stand improvement activities in grand fir and white fir stands should be consistent with sound management practices aimed at preventing or reducing root disease problems. The roots of trees attacked by fir engravers should be examined for evidence of root diseases. If root diseases are found, stand treatments designed to reduce them should be employed (see Diseases section). Discriminating against true firs, in favor of seral pine, larch, and Douglas-fir that are resistant to root disease, would likely be part of this equation.

Salvage of fir engraver-killed trees is often necessary in timber management areas to recover wood volume from sound trees. Trees attacked and killed by fir engravers deteriorate and lose value rapidly. True firs should be salvaged within a year of their death in order to circumvent completion of fir engraver brood development, and limit amount of weather-checking and other losses from deterioration or degradation (such as caused by ambrosia beetles and woodborers). Strip-attacked trees not killed by fir engravers should also be promptly salvaged. Repeated entries, however, should be avoided since they could result in increased problems from root disease, which in turn might lead to additional mortality from fir engravers in subsequent years: The possibility of this undesirable outcome should not preclude salvaging altogether, but rather, salvage should be included as a part of an overall plan to silviculturally manage stands in a way that addresses stand or site problems. From the standpoint of stocking levels, Cochran (1981) has provided some preliminary guidelines for east-side white and grand fir. His recommendation is to thin from below to maintain stocking levels between 50 and 75 percent of normal, once trees reach commercial size.

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Western Pine Beetle (Dendroctonus brevicomis LeConte)

Hosts and Community

The western pine beetle is a native bark beetle and an important enemy of pine forests in the West. Keen (1952) considered it to be the most important insect enemy of ponderosa and Coulter pine within the range of these trees, all the way from Baja California to western Canada. The western pine beetle has been intensively studied and has proven to be an important factor in the ecology and management of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) throughout the range of this host species (Miller and Keen 1960).

Historically, the western pine beetle has done most of its damage in California pine regions (DeMars and Roettgering 1982), but this insect has caused substantial loss of merchantable pine volume over the years in Oregon, Washington, and other locations throughout its host's range. Ponderosa pine is the only important host of the western pine beetle in the Blue Mountains. There, the beetle has at times killed trees of all ages and vigor classes (down to 5 or 6 inches in diameter (dbh)), including apparently healthy trees. The other conifer host of the western pine beetle is Coulter pine (*Pinus coulteri* D. Don), but this species does not occur in the Blue Mountains.

Lodgepole pine (*Pinus contorta* Dougl. ex Loud.) has been reported to have been attacked under natural conditions occurring in close proximity to groups of ponderosa pine undergoing heavy attack by western pine beetle. Such attacks were considered to be due to an overflow of beetle population from the ponderosa host trees (Miller and Keen 1960). However, in one case there was evidence of brood production in lodgepole pine, but the instance was considered to be an anomaly. Therefore, because attack of lodgepole pine by western pine beetle occurs only under rare circumstances, lodgepole pine is considered to be an "accidental" host for western pine beetle. The same applies to sugar pine (*Pinus lambertiana* Dougl.), for which the only verified record of attack by western pine beetle occurred under experimental conditions where the beetles were forced to attack logs in cages (Miller and Keen 1960). In this case, the beetles entered the bark and constructed short egg galleries, but did not produce brood.

Ponderosa pine in the Blue Mountains grows as a shade-intolerant seral species, typically occupying well-drained, mid- and low-elevation, drier sites. Its high drought tolerance enables it to form ecotones with juniper and sage species at the drier end of its range, but it also occurs on some wetter sites, interspersed in communities dominated by Engelmann spruce (*Picea engelmannii* Parry ex Engelm.). Western pine beetle can commonly be found in any of the ponderosa pine plant associations of the ponderosa pine series (CP). It also occurs in the grand fir series (CW) and the Douglas-fir series (CD), where ponderosa pine constitutes some component of the coniferous species in those plant communities.

Biology

Western pine beetles usually breed in and kill trees that are scattered, overmature, slow-growing, decadent, or diseased and root-rotted (Cobb et al. 1974). Also affected are trees weakened by stand stagnation, lightning, fire, mechanical injury (DeMars and Roettgering 1982), and windfalls (Furniss and Carolin 1977). Other stand conditions that can lead to group killing of trees by western pine beetle are: High density and overstocking for young, even-aged sawtimber; and the presence of high density clumps of pine in stagnating mixed-conifer stands (DeMars and Roettgering 1982).

Host selection and colonization are initiated by the female beetle. Host odors produced by a susceptible pine are believed to be the key factor in attracting the adult female which, soon after arrival at a pine, bores through its bark and releases a pheromone which draws in both males and other females. Visual cues, and perhaps random searching, may also be important in host selection (Coulson 1979).

Soon after the female beetle begins excavation of a winding S-shaped gallery, she is joined by a male. After mating, the female oviposits in niches cut into alternating sides of the egg gallery. About 60 eggs are laid in each gallery (DeMars and Roettgering 1982). Termination of attack and "switching" to other unattacked nearby trees by beetle populations is accomplished by the release of antiaggregating pheromones in combinations with aggregating pheromones (Wood 1982). The process of termination and switching by which the western pine beetle aggregates appears to be complex, and is not clearly understood.

However, simple attack by the western pine beetle is not the only contributing factor in the death of the host pine. Also important is the fact that adult beetles attacking a host carry spores of a blue-staining fungus, *Ophiostoma wageneri* (Goheen and Cobb) Harrington [=*Ceratocystis minor* (Hedg.) Hunt], in special pouch-like structures in their heads called mycangia (DeMars and Roettgering 1982). Beetles inoculate the pine's sapwood with the fungus, and it aids the insect in killing the host tree. It may also provide nutrition to beetles in later developmental stages (Coulson and Witter 1984). In return, the generation of larvae produced by the attacking adults picks up fungal spores (which collect in the mycangia as the brood feeds on the middle and outer bark) and distributes them during the next attack. Thus passing on the symbiotic beetle/fungal relationship to succeeding generations, and reinforcing the obligatory nature of the partnership.

Whitney and Cobb (1972) discovered three other fungi in non-stained areas of sapwood on ponderosa pine infested with western pine beetle. Researching further, they isolated two of the fungi from the beetle mycangium, and one from the body surface of the beetle. They suggested that these non-staining fungi may play a role in causing the death of ponderosa pine trees attacked by western pine beetles.

In the Blue Mountains, western pine beetle produces two generations each year, with attacks occurring in early June and late August. The initial attacks are made at upper midbole and then progress up and down the trunk from that point (Miller and Keen 1960). Eggs produced from these attacks begin hatching from 1 to 2 weeks after they are laid. The newly hatched larvae begin feeding by mining across the grain in the cambium region until the third instar is reached (Furniss and Carolin 1977). The initial mines are short and larvae soon turn outward, working their way to the middle or outer areas of the bark. Near the end of the 4th and final instar, each larvae bores further into the bark and forms an enlargement of its gallery in which to pupate (Miller and Keen 1960).

The pupation period for western pine beetle may last from one to two weeks when conditions are favorable. When cold periods occur during the pupation period, its duration can be extended several weeks. Following transformation to the adult stage, the adults bore their way almost to the surface of the bark and rest there for 7-14 days before finally emerging from the bark surface and taking flight (Miller and Keen 1960).

The conditions under which beetles increase numbers to outbreak-sized populations and cause mortality to host trees in a given area are influenced by several factors: Food quality, quantity, host stress, and reduced flow of resin (oleoresin exudation pressure) are among those factors. The availability of suitable host material in trees that are not so healthy that they are able to resist attack and pitch beetles out, is a key factor in enabling beetles to increase to outbreak. Trees with thick, nutritious phloem that undergo sudden and severe moisture stress are ideal habitat for attacking western pine beetle, and enable large broods to be produced (DeMars and Roettgering 1982). Thus, ponderosa pine susceptibility increases when trees undergo moisture stress. Population buildup of western pine beetle is common during periods of protracted drought, and much of the increase in western pine beetle-caused tree mortality in the Blue Mountains during past decades is related to this condition, as well as to overcrowding in stands. Drought has been an important factor in past decades in promoting outbreaks and losses of ponderosa pine from western pine beetle. For example, Furniss and Carolin (1977) indicate that during the severe drought of the 1920's and 1930's, losses of up to 60 to 90 percent of the ponderosa pine forest on extensive areas were recorded. And analogous drought conditions again pertain at present.

Terminations of outbreaks occur through a combination of factors including tree resistance, buildup of natural enemies, and prolonged cold temperatures. The resin production capability seems to be a prime factor in the ability of trees to resist beetle attack. Many trees are able to produce sufficient oleoresin exudation pressure that they pitch beetles out as resin canals are ruptured by attacking adult beetles, or the resin may flow into the gallery area and soak phloem tissue, killing the adults and eggs as they are deposited. DeMars and Roettgering (1982) indicate that more than 80 species of predaceous and parasitic insects have been found to be associated with western pine beetles. These invertebrate enemies, along with woodpeckers, play a significant role in mortality of western pine beetle, and help to maintain endemic levels of bark beetles, but their action alone cannot control outbreaks. Extended cold periods (below -20°F) have been shown to cause heavy brood mortality (Miller and Keen 1960), but populations eventually recover after a few generations. The combination of these, and other natural factors, can eventually reduce outbreaks to endemic levels.

History

Outbreaks of western pine beetle have been observed, and surveys made, in the pine regions of the West since 1899 (Hopkins 1899; cited in Miller and Keen 1960). Most of the early attention to outbreaks of western pine beetle centered in the California and southern Oregon regions, where much survey, control, and research work on western pine beetle was carried out. Few references to outbreaks of western pine beetle in the Blue Mountains could be found in the literature dating earlier than about 1930, as summarized by Miller and Keen (1960). However, it was clear that western pine beetles were partially responsible for some mortality of yellow pines [ponderosa pines] during the mountain pine beetle outbreak in northeastern Oregon that occurred just after the turn of the century (Burke 1990).

Beginning in about 1930, the Bureau of Entomology, in cooperation with the Forest Service, the Park Service, the Office of Indian Affairs, and other land management agencies expanded annual forest insect surveys on a region wide basis to obtain information on intensity and trends of forest insect infestations, especially bark beetles (Miller and Keen 1960). Enormous losses of ponderosa pine through the actions of western pine beetle at around this time, and in prior years, earned the western pine beetle the reputation of being ranked as "forest enemy number one" by entomologists and foresters in the West. During these early years, most outbreaks occurred in stands of mature or overmature timber, containing trees of poor vigor.

A good share of the blame for increasing ponderosa pine losses due to western pine beetle outbreaks throughout much of the western pine regions during these early years appears to be related to drought-caused decline in growth rates. Miller and Keen (1960) state, for example that:

> "Increasing mortality of ponderosa pine in eastern Oregon after 1924, while charged to bark beetle attack, was suspected of being primarily caused by drought conditions and lowered tree vitality. Drought conditions were somewhat improved in 1927, and the rate of loss dropped the following year. More years of drought followed, and a most critical condition occurred in 1931 and 1932...In general it can be claimed that beetle-caused losses are inversely related to the growth rate...A steadily declining growth rate over a period of several years prior to 1930

was followed by a very rapid rise in the loss level; on the other hand, the general rise in growth rate from 1934 to 1940 was accompanied by a fluctuating, but nevertheless, substantial lowering of the loss level."

The decade from 1928 through 1937 was marked by fluctuating populations, with losses in ponderosa pine stands ranging from a high of 24 percent of the stand on 270,000 acres of the Snow Mountain area to a low of 5 percent on several Washington and Oregon areas. Damage by western pine beetles in the Blue Mountains forests of northeastern Oregon and southeastern Washington was, overall, comparatively light during this period, except for the period 1931-1933, as indicated above. The outbreak that apparently started in 1931 flared up suddenly and is said to have caused tremendous losses in 1932. One report (USDA 1939) stated an example of the ponderosa pine losses in The Blue Mountains Subregion in the following way:

> "On one 80-acre plot on the Ochoco National Forest, over 17 percent of the stand was killed in that one year [i.e., 1932]. Then following the cold winter of 1932-33, the epidemic subsided as quickly as it had developed, and except for rather limited areas has remained at a low level during the last five years."

The report goes on to summarize the western pine beetle situation by National Forest. Infestations of western pine beetle on the Malheur National Forest were said to vary considerably in different portions of the Forest, but for the Forest as a whole, it was estimated that approximately 10 percent of the pine in stands had been killed in the 10 years leading up to, and including 1932. Heavy losses of ponderosa pine on the Umatilla National Forest, particularly on the western edge of the Forest in the Kinzua Unit, occurred during the period from 1931 to 1933, but dropped off thereafter. For the most part, on the Wallowa and Whitman National Forests western pine beetle-caused losses during the beetle epidemic of 1931-1933 were comparatively light. The reason was given that the early development of the lumber industry on these Forests, due to the demands for mining, agriculture, and transcontinental railroad development, resulted in the removal of much of the beetle-susceptible timber in high hazard areas before the general beetle epidemic occurred.

Western pine beetle infestations in the Blue Mountains during the decade 1938-1947 remained in a state of flux, but levels were comparatively low relative to the previous decade. During the mid- to late-1940's there was increasing interest in managing ponderosa pine stands by making light selection cuts for the removal of beetle-susceptible trees. And by the end of the decade, this became a standard practice in eastside forests. This practice of selectively logging the high-hazard trees apparently resulted in significant decline in the acres infested by western pine beetle in the Blue Mountains (Fig. II-17).

Populations of western pine beetle began increasing in the Blue Mountains after 1958 and rose to a high in 1962, before dropping sharply the next year because of increased efforts to salvage infested trees and remove those--mostly mature trees--deemed susceptible to the beetle. Also, the large amount of ponderosa pine and other conifer species windthrown when Hurricane Frieda struck Oregon and Washington on October 12, 1962 left entomologists and foresters pondering the need for chemical treatment for control of beetle populations that might invade the windthrown timber, in some areas, in the face of a sluggish lumber market. Apparently, this action did not become necessary, however.

Through the next couple of decades, western pine beetle populations fluctuated up and down in the mature stands of ponderosa pine, promoted during some years by hot, dry summers (e.g. 1967). As the 1970's came to a close, much of the old-growth ponderosa pine had been liquidated through selection harvesting practices. Many of these trees were killed over the years by bark beetles while others were harvested in green-tree sales or removed because of their beetle risk. Other trees were killed in groups that were attacked by outbreak levels of western pine beetle or mountain pine beetle

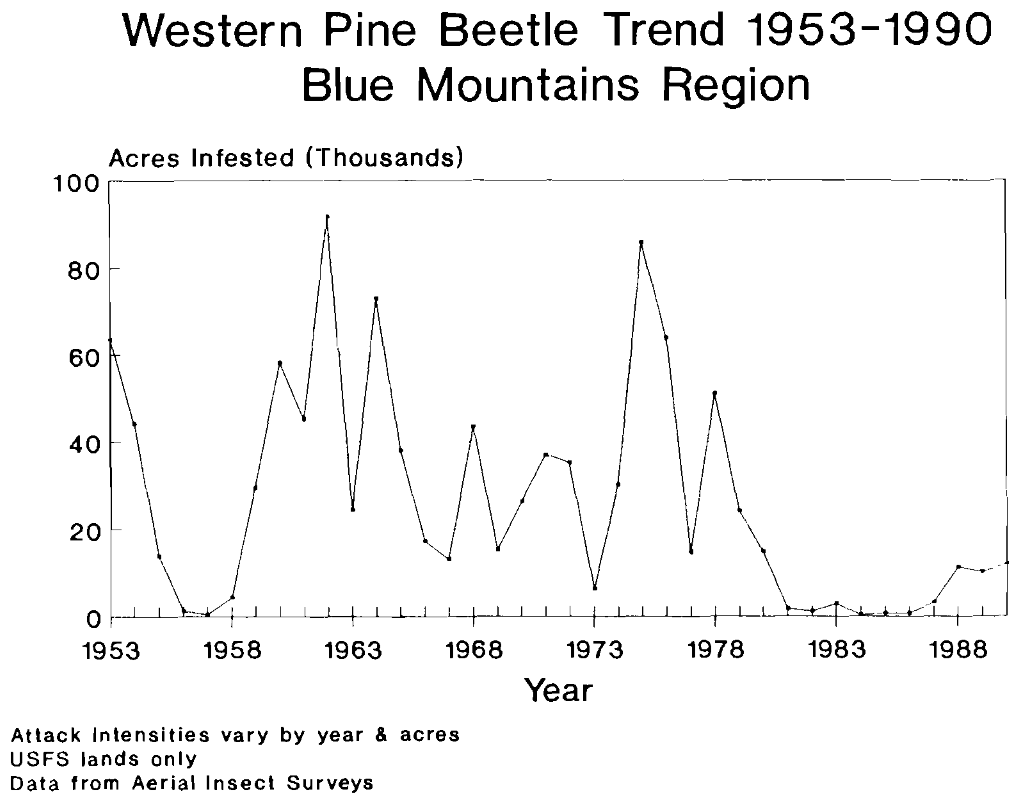


Figure II-17
Western pine beetle infestation trend from 1953 thru 1990 on National Forest lands (Malheur, Umatilla, and Wallowa-Whitman) in the Blue Mountains. (Based upon Aerial Insect Detection Survey data)

(*Dendroctonus ponderosae*). Some of these groups were overstocked stands of second-growth ponderosa pine. With fewer old, large, susceptible ponderosa pines remaining, it appears that western pine beetle has begun to attack unmanaged, overstocked second-growth stands more frequently. These are the type of stands that characterize the hosts for recent increases in beetle activity, especially as they become moisture stressed from 4 or 5 years of drought.

Stand Conditions

Under normal conditions, the western pine beetle breeds in a few overmature trees, in windfalls, unhealthy trees, or in trees weakened by drought, stand stagnation, or fires (Keen 1952). DeMars and Roettgering (1982) have characterized the conditions affecting outbreaks in terms of the influence of food supply, natural losses due to attacking beetles, tree resistance, natural enemies, and cold temperatures. In terms of the stand conditions, they state that the availability of suitable host material (nutritious phloem and inner bark) is a key condition influencing outbreaks. Drought stress is also important, in that healthy trees that undergo sudden and severe moisture stress are key to buildup of western pine beetle populations. When deprived of adequate moisture, these otherwise healthy trees cannot produce the necessary resin flow to resist attack by pitching out beetles or soaking the phloem tissues surrounding the egg galleries with resin. It is in these trees that populations build to outbreak levels.

Any of several factors which contribute to poor tree vigor (and hence, stand vigor) can promote the increase in western pine beetle populations, giving rise to outbreaks. Mature and overmature stands of high basal area exposed to rootlet pathogens, air pollution, cultural damage, water stress, and other factors are considered to create high hazard states for beetle outbreaks (Coulson and Witter (1984).

The western pine beetle becomes considerably more aggressive under epidemic conditions and kills apparently vigorous trees of all age classes having bark sufficiently thick to protect the insect in its development (Keen 1952). It has been noted (Keen 1952) that trees under 6 inches in diameter are seldom attacked, nor does this beetle breed in limbs. However, we have found several instances in the Blue Mountains during the current drought cycle where western pine beetle, along with pine engraver (*Ips pini*), have attacked overstocked, stagnated pole-size stands of ponderosa pine, and killed groups of trees down to 4 3/4 inches (dbh). Most of the time, western pine beetle fails to produce successful brood in these small diameter trees, presumably because of the comparatively thin bark and the drying out of the cambium and phloem.

Early studies on stand susceptibility to western pine beetle focused on site quality as a factor influencing beetle outbreaks (Miller and Keen 1960). Indeed, some studies did show that sites of low quality exhibited greater loss than high quality sites, while other studies could not show a correlation of beetle susceptibility with site quality. In some cases, relatively poor sites were found to experience very few beetle-caused losses, while some good sites sustained extremely high mortality. Growth rate and individual tree vigor are frequently independent of site quality, and these characteristics, which affect the susceptibility of trees and stands to western pine beetle, seem to be more greatly influenced by other factors such as stand density, local precipitation, and competition. Thus reducing the importance of the factor of site quality itself.

Occurrence

Trends of western pine beetle in the Blue Mountains during the last decade are shown in Figs. II-18. Beetle activity in the Blue Mountains over the last decade, though low compared to previous decades, has been increasing during the last several years due to drought stress on trees (Figs. II-18).

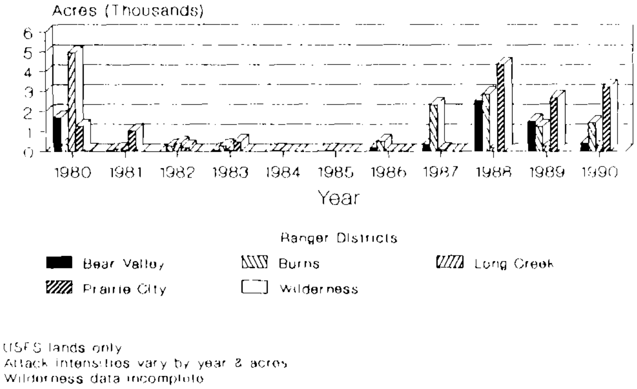
Most of the western pine beetle infested acres occurred in stands on the Malheur and Wallowa-Whitman National Forests. Infestations on the Umatilla National Forest have been comparatively few (Fig. II-18). Regarding western pine beetle trends during the last 5 years, it can be shown that though general trends of infestation tend to be similar, actual population levels and affected acres vary, independently, by Ranger District from year to year. However, it should be noted that this may be a reflection of the differences in aggressiveness by which different districts undertake treatments to reduce susceptibility of stands to western pine beetle.

Suppression

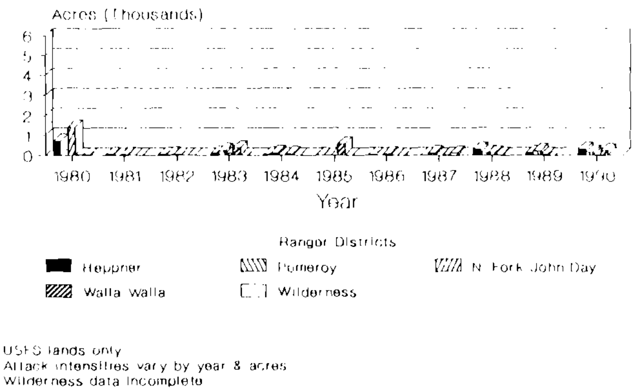
In the most simplistic sense, there are two basic methods of controlling damage caused by western pine beetles: Eliminating beetle populations, or eliminating the host trees on which the beetles feed (USDA 1939).

Direct control of western pine beetle since about the 1920's, or perhaps earlier, has involved the destruction of insects in infested trees before they have had a chance to develop to maturity, escape, and attack other trees. Many methods of controlling western pine beetle have been investigated or tried since the turn of the century, but few have offered much promise. And some were clearly impractical or gave negative results.

Western Pine Beetle Infested Acres
Malheur National Forest



Western Pine Beetle Infested Acres
Umatilla National Forest



Western Pine Beetle Infested Acres
Wallowa-Whitman National Forest

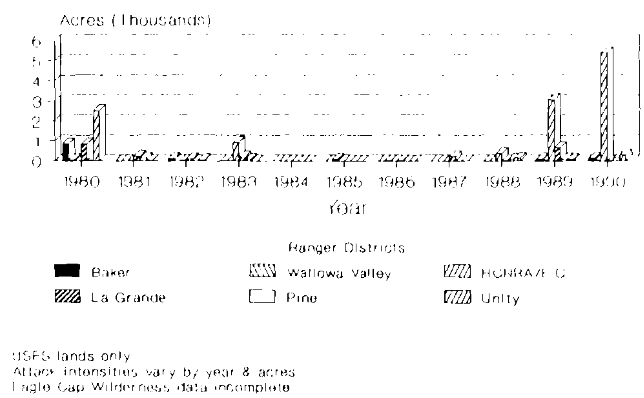


Figure II-18
Acres with visible western pine beetle-caused tree mortality on National Forests in the Blue Mountains from 1980 thru 1990. (Based upon Aerial Insect Detection Survey data)

Miller and Keen (1960) cite an interesting list of techniques: (1) Fell-peel-burn; (2) pit burning; (3) decking and burning; (4) use of fuel oils in burning; (5) use of goop (an incendiary material used in aerial bombing in World War II) in burning; (6) use of solar heat to kill broods; (7) use of toxic oils to kill broods (mineral oils in mixture with soluble insecticides, such as naphthalene, creosote, paradichlorobenzene, orthodichlorobenzene, DDT, BHC, chlordane, toxaphene, and ethylene dibromide); (8) residual-type sprays (use of synthetic organic contact insecticides, such as DDT, BHC, and lindane); (9) scoring felled trunks (stripping bark about 4 inches wide the length of a felled, infested log to hasten drying and destruction of brood); (10) burying infested bark in soil; (11) electrocution; (12) radio waves; (13) fumigation (e.g. methyl bromide); (14) injection of infested and high-risk trees (e.g. powdered copper sulfate, sodium arsenate, zinc chloride, nicotine sulfate, carbon bisulfide, and carbon tetrachloride); and (15) trapping methods (e.g. light traps, bait traps, trap trees).

Of all these methods, the only one that became widely adopted for western pine beetle control was the fell-peel-burn method. This method, which was called simply, "Direct Control," gained in popularity and came into wide use during the Direct Control Program years of 1933-1938. Direct control measures using this method consisted of felling the infested trees, peeling, and burning the bark late in the fall, or in winter or early spring (Keen 1952). Sometimes the trees are treated with an insecticide or physically removed, beetles and all, from the forested areas (Hall and Pierce 1965). Keen (1952), in addressing the use of the fell-peel-burn method of controlling western pine beetles, stated that:

> "Such control work has been successful in reducing infestations during critical periods, but cannot be relied on to eliminate them and must be repeated until natural control factors become operative."

The Direct Control Program was undertaken because the nature of much of the losses from western pine beetle previous to that time occurred in the form of endemic (low-severity) infestations scattered simultaneously over large areas, and were, therefore, impractical to control. However, epidemic outbreaks could often be successfully handled in their incipiency by Direct Control (USDA 1939).

On the other hand, Direct Control has its limitation. Hall and Pierce (1965) point out the main failings of Direct Control are:

> "High cost of accomplishment, near impossibility of finding all the infested trees before the beetles escape, and the fact that the treatment does little to alter any of the basic conditions which encouraged the outbreak in the first place."

The other method of controlling damage caused by western pine beetle (eliminating the susceptible host trees) employs a silvicultural practice aimed at preventing bark beetle epidemics through what is called the Sanitation Treatment. This method utilizes a specialized system of risk-rating to first identify the most vulnerable trees, and then remove these susceptible trees from the stand, thereby providing a high degree of protection for the rest of the stand. Hall and Pierce (1965) suggest that in order to provide protection from bark beetle epidemics for periods of up to one or more decades, usually 10 to 15 out of each 100 trees must be removed. Also, periodic entries for Sanitation Treatments must be conducted when trees in the stands reach stages of high vulnerability. The California Pine Risk-Rating System described in a subsequent section can be used to determine the current probability of attack by insects. When utilized as a logging practice (to reduce food opportunities for beetles, and to salvage values before they are damaged), the California Pine Risk-Rating System is usually called "Sanitation/Salvage" (Smith et al. 1980).

It is important to note that the Sanitation Treatment, though an effective method of reducing western pine beetle-caused losses to ponderosa pine in the Blue Mountains, is also not without its drawbacks. The value of the high risk tree or trees being removed by commercial operator must exceed the cost of removal. In addition, the method is applicable only in the mature, slow-growing ponderosa pine stands of the eastside type. Trees from sapling or pole stands usually do not display visible symptoms of high risk, and, therefore, cannot easily be identified by the methods to risk-rate susceptibility of trees, such as the California Pine Risk-Rating System. In this case, a stand hazard-rating technique must be used to determine vigor. It should operate much in the same way as those employed for determining mountain pine beetle hazard, and treatment of the entire stand (e.g. thinning) must occur rather than individual tree removal. Finally, because the sanitation-salvage requires the removal of such a high percentage of risk trees to achieve survival of residuals for 10 years or more, the resultant losses of shade and aesthetic values make using this method inappropriate for campgrounds, parks, and recreational areas. This is due to the fact that the emphasis in such areas is on retaining trees for the benefits they provide, rather than on removing them for their present economic value (Hall and Pierce 1965; Miller and Keen 1960).

Effects

The impacts and effects of western pine beetle outbreaks on resources in the National Forests of the Blue Mountains are not nearly as serious as those caused by the mountain pine beetle in the same timber type. Except for rare conditions of extreme timber mortality over large areas, such as has occurred in the distant past, western pine beetle outbreaks would probably have little effect on most resources in the Blue Mountains. This appears to be supported by Ranger District responses to the 1990 Forest Health Questionnaire (see Appendix F). The vast majority of districts reported that management allocations, including riparian, wildlife, special, timber and wildlife, wilderness, old-growth, and viewshed, are impacted by western pine beetle at only low and medium intensities on their districts.

The potential significance of western pine beetle epidemics in some situations, however, is great. DeMars and Roettgering (1982) report that extensive tree killing by western pine beetle may deplete timber supplies, adversely affect levels and distributions of stocking, disrupt management planning and operations, and increase forest fire danger by adding to available fuels. Indeed, these factors were of great concern to foresters and entomologists in the past (Cowlin et al. 1942). They could become a greater problem in the future as well, as the large numbers of second-growth ponderosa pine stands in the Blue Mountains grow into maturity and beyond, without adequate silvicultural treatment and management.

Hazard Rating

Systems to rate the susceptibility of trees to western pine beetles are an outgrowth of tree vigor classification systems designed for silvicultural purposes (Graham 1963). Dunning's Classification (Dunning 1928) was one of the first tree vigor classification systems. Keen (1936) later developed the classic "tree classification system" for western pine beetle in old-growth ponderosa and Jeffrey pine. Keen's system was based on age and crown vigor, and was patterned somewhat after Dunning's earlier classification. Keen (1943) later modified his tree classification system by redefining his tree classes to allow easier placement of borderline trees in the class which best represented their growth rate and mortality risk. It is believed that additional changes and refinements to Keen's classification system formed, at least in part, the basis for the California Pine Risk-Rating System (which is still in use today), although the historical development is not entirely clear.

The California Pine Risk-Rating System provides a means to rate the current probability of attack of ponderosa or Jeffrey pines by western pine beetles or Jeffrey pine beetles, respectively. The System classifies individual tree risk based on readily recognizable crown characteristics. The System has been widely used in California, southern Oregon, and eastern Oregon and Washington, and has been found to be highly effective in reducing bark beetle-caused losses on applicable forest sites (Smith et al. 1981). Applications of the System indicate that removal of 10 to 15 percent of the stand volume, rated as high-risk trees, reduces subsequent losses from western pine beetle by as much as 80 percent over the next 20 years or more (Smith et al. 1981).

The California Pine Risk-Rating System was developed for use in virgin, mature, and overmature ponderosa pine or Jeffrey pine stands. The limitations of using this type of risk-rating system in young to intermediate-aged stands has been previously mentioned in the Suppression Section.

The California Pine Risk-Rating System has undergone two important modifications that simplify its use and increase its utility. A penalty scoring procedure has been added which makes it easier to use for those who may be unfamiliar with it. The penalty scoring procedure for rating high-risk trees is reproduced in Smith et al. (1981). Another enhancement to the System has been the derivative of a stand hazard classification procedure to rate the relative need of areas for pest management attention, either in the form of western pine beetle survey or control (Smith et al. 1981). Unfortunately, the details of the procedure are documented in unpublished reports on file at the Pacific Southwest Research Station, and may not be available. Since few large, virgin stands of ponderosa pine remain in the Blue Mountains, the need to classify entire stands for susceptibility to western pine beetle may be minimal.

Models

Presently, there are no computer models available to simulate ponderosa pine losses to western pine beetle, or to simulate beetle population dynamics. The only known model for the western pine beetle was developed by Keen and Merriam (1953). This is a regression equation for determining expected future ponderosa pine loss in terms of average percent of stand killed per year. The details of the development of the equation are unpublished, but Miller and Keen (1960) have provided the equation and have defined the variables used in the model. It is not known how successfully this model has been used, if at all, in the Blue Mountains.

Management

Western pine beetle appears to have been less of a problem in mature or overmature ponderosa pine during this half of the century than it was in the first half. Although it is still a mortality factor, much of the virgin ponderosa pine stands have been liquidated in the Blue Mountains. Thus, it is uncommon to see western pine beetle outbreaks developing in stands where an occasional large, old ("yellow-belly") ponderosa pine is killed by western pine beetle, unless the stand is overstocked and unmanaged. Most infestations of western pine beetle nowadays appear to be occurring in younger pole- and small sawlog-size stands that are in need of stocking control, are drought-stressed, or are susceptible to bark beetles due to other factors.

Where virgin, mature, or overmature stands still exist, current management recommendations still prescribe a sanitation-salvage cutting. The most effective method of reducing losses from western pine beetle is through the removal of susceptible or high-risk trees in a selective cutting. Susceptible trees can be recognized by their poor vigor; declining growth rate; dying tops and twigs; short, sparse foliage of poor color; and advanced age. Infested trees have reddish boring dust in bark crevices and small pitch tubes. They may also be heavily infected with dwarf mistletoe, or have root disease, or may have been struck by lightning (DeMars and Roettgering 1982).

Younger, dense stands of sawtimber in the 70- to 80-year old age classes will respond to thinning, and can be managed for western pine beetle resistance by effective stocking control. Controlling stand density to reduce western pine beetle risk will also have the added benefit of providing resistance to mountain pine beetle and pine engravers, as well. DeMars and Roettgering (1982) recommend reducing stocking to 55 to 70 percent of the basal area needed for full stocking. This action will relieve the competitive stress among the residual trees, improve their vigor, and will allow them to successfully pitch beetles out if they are attacked.

Individual high-value trees growing in a park, campground, recreation, or administrative area may be predisposed to beetle attack if trees are stressed by soil compaction over root systems, mechanically injured, weakened by drought, or are proximal to an active infestation of beetles in adjacent stands. Such trees can be prevented from incurring lethal attacks of western pine beetles by a residual protective bark treatment with registered contact insecticides. The insecticides carbaryl and lindane are registered for this application. The details of treatment are given in Hamel (1983). This type of treatment must be repeated each year during the period when western pine beetle populations are active in adjacent stands and should continue until beetle populations decline to endemic levels.

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Pine Engraver (*Ips pini* (Say))

One other forest insect that should be mentioned is the pine engraver (*Ips pini*). It is a lesser threat than the other insects mentioned, and so, due to constraints on time and space will not receive full treatment. The following sums up the role of *Ips pini*:

The pine engraver beetle is typically found in overstocked, young sapling and pole-size lodgepole and ponderosa pines, although it has at times killed trees of larger diameter. Usually, older trees are attacked in the tops, killing the top, while the bole is attacked by other species of bark beetles, including mountain pine beetle, western pine beetle, and others. Sapling and small pole stands in or near thinning, logging, or blowdown areas are particularly vulnerable. Pine engraver beetles produce two generations of beetles per year in the Blue Mountains. The first generation is usually the only one that kills trees. Beetles, which overwintered as adults readily attack fresh slash and blow-down in the early spring, in which they produce brood; the first generation of beetles. These populations are usually large and quickly reach maturity, and unless a supply of fresh green slash is available to absorb emerging beetles, the insects will attack and kill live, green, sapling- or pole-size trees in nearby ponderosa or lodgepole pine stands. Outbreaks are relatively common during droughty periods, such as the Blue Mountains has experienced for the last four or five seasons. Outbreaks which develop in this manner are usually short-lived, lasting no more than a season or two, and control is generally unnecessary. Populations of pine engraver are easily controlled through proper timing of logging and thinning activities and treatment of the resulting debris. Periodic outbreaks of pine engraver will most likely continue, especially during periods of drought and where improper logging or thinning practices are employed. The most significant factor with respect to pine engraver epidemics in the Blue Mountains National Forests, is their ability to reduce stocking below desirable levels, and sometimes completely destroy residual trees in stands or plantations being thinned. Overall, the adverse effects of the pine engraver in the National Forests of the Blue Mountains are probably negligible.

IMPORTANT FOREST TREE DISEASES IN THE BLUE MOUNTAINS

Introduction

Forest tree diseases in stands of the Blue Mountains cause very serious losses that affect all resources. Damage is believed to have increased such that unit losses in volume, stems and basal area are higher now than any time in the last 100 years. This surge in disease-caused losses is the result of increased stand susceptibility. Changes in stand and site characteristics that have led to this increased damage susceptibility include the following factors:

(1) Most stands have a higher proportion of susceptible shade-tolerant species. Stocking levels are excessive in many stands. This is the result of an effective program of fire suppression and past selective harvesting practices.

(2) Stress such as soil compaction and displacement are more prevalent than in the past due to harvest activities.

(3) There is an increase in pathogen inoculum, especially with respect to that infected material that causes root diseases.

Some levels of disease occurrence and mortality associated with tree diseases tend to provide for stand diversity and promote benefits for other resources. Root diseases predispose trees to windthrow which provides large down woody material. Stem decays provide habitat in trees for cavity nesting animals. Dwarf mistletoe brooms provide roosting cover sites for certain birds. Thus, some level of disease incidence is desirable. However, when these damages become excessive, and resource goals are being adversely affected, management direction needs to reduce disease impacts.

Forest diseases cause damages that are usually less visible or appear to be less dramatic than those caused by insect pests. Disease-caused losses occur over long portions of time, often over the entire life or rotation of a stand. Further, losses occur at relatively constant rates, although sometimes they increase during periods of environmental stress. Disease losses, while usually not as visible as defoliation or mortality that occurs during insect epidemics, over a rotation, may be comparable to or even exceed insect-caused impacts as is often the case with diseases such as stem decay. Trees may have indicators such as wounds or fungus fruiting bodies, but until trees break, are windthrown, or are cruised or cut, losses associated with cull and defect are not realized. Disease losses may be gradual, e.g. root diseases. As diseases progress, tree mortality occurs over a long period of time, and only a small proportion of trees dying each year. Sites become understocked; and therefore less productive. Diseases may also result in growth loss; dwarf mistletoes may have this effect for many years before finally causing mortality.

Losses caused by forest diseases are difficult to estimate. Growth loss, scattered mortality, and tree defect are not identified as readily as most insect impacts, in the annual Aerial Insect Detection Survey conducted by the Pacific Northwest Region. Disease losses must be estimated from ground samples or by using models that use stand data. Stand examinations and the Timber Inventory have been used for years to quantify timber volumes and other resource values on the Forests. While pest occurrence and pest-caused damage have historically been data collection requirements, accurate estimates of existing or future disease-caused losses have not been generated from these samples for two main reasons:

(1) Models have either not existed or not accurately estimated the impacts on growth and yield from root diseases, stem decays, dwarf mistletoes and other diseases.

(2) Field data collectors have not had the training required to accurately identify and quantify disease occurrence and damage. While collecting selected data on 10-year measurements of Forest Inventory plots on the Wallowa-Whitman, Wenatchee, and Okanogan National Forests, Filip et al (1990b) found that 19 of 94 stands had decreased in average Dwarf Mistletoe Rating (DMR). This was believed to be highly unlikely. This reduced their confidence in the remaining plot DMR data and concluded that the DMR ratings from the majority of the previous plot readings were inaccurate. These plots had been read by a number of different crews. Dwarf mistletoe data is considered much easier to read than data such as root disease identification. However, better training of field crews and recalibration and development of stand resource models is expected to provide better estimates of disease-caused losses.

In 1986 and 1987, pathologists sampled 36 (all randomly-selected) managed and 18 unmanaged stands on the Wallowa-Whitman National Forest to estimate pest caused damage (Schmitt et al 1991). Results of disease occurrence in all managed stands are shown in Figs. II-19 thru II-25. It is important to realize that the values reported are underestimates of actual incidence of diseases and pest-caused damage. In many cases stem decays and root and butt rots are not identified unless trees have indicators of infection or damage. Schweintizii butt rot of Douglas-fir and tomentosus root and butt rot of Engelmann spruce are seldom recognized on standing live trees since indicators are not common. Most dwarf mistletoe-caused mortality (and severely infected trees) are removed in stand entries of managed stands, therefore corresponding values for dwarf mistletoe infestation in unentered stands are much higher. However, disease occurrence is believed to be relatively similar on the Malheur and Umatilla National Forests, so Figs. II-19 thru II-25 can be taken as roughly analagous for all three Forests. Insect losses are not shown for the 1986 and 1987 Wallowa-Whitman survey. Since this evaluation, insect-caused damage has greatly increased. Disease-caused damage is believed to be more stable, thus these infestation figures, although 4 and 5 years old, are still appropriate.

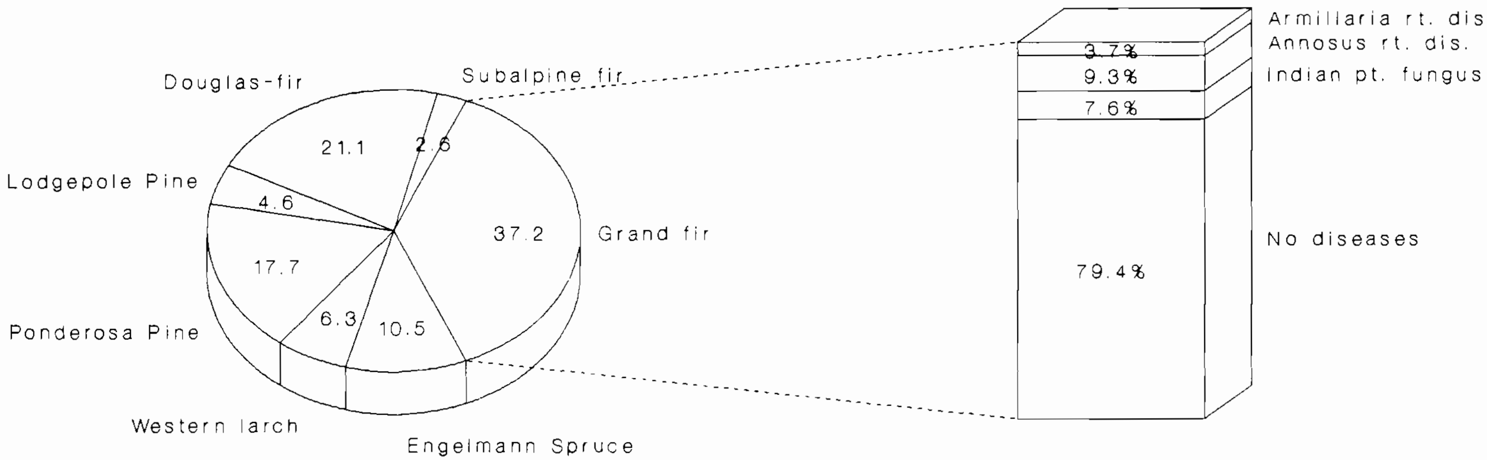
Major forest diseases in the Blue Mountains include a variety of root diseases, stem decays, and dwarf mistletoes. The forest diseases of most concern to managers of Blue Mountains Forests have been categoried in the following pages. Some of these pests occur over large geographic areas and across many different host types, others are relatively localized and unique to the Northwest. Most of these pests affect forest stands of the Blue Mountains differently than they do other areas where these diseases occur, thus creating differences in damage, affected hosts, and effective management options. The following discussion elucidates the most up-to-date information and state-of-the-art management options for reducing resource impacts from diseases in the Blue Mountains. This compilation includes literature reviews, findings of recent and on-going research, and the opinions of practicing pest management specialists working in the Northwest. The information on the impacts, occurrences, and effects is based on responses to a questionnaire by various specialists representing a variety of resource disciplines from all Ranger Districts on the Blue Mountains National Forests.

It is important to recognize that most pest-caused damage and mortality are the results of pest complexes. Root diseases and bark beetles are closely associated. Root disease-infected trees are weakened, and frequently, killed by beetles. Two or more different root diseases are often found together in centers of mortality. Often mortality is attributed to the pathogen or pest that displays the most recognizable signs and symptoms. Root diseases that need to be detected by laboratory culture are almost always missed.

Management options presented in this section are considered the most effective means of minimizing pests and pest-caused damage. Concerns for other resources and values will often require that these options be modified, perhaps reducing their effectiveness. The options presented here must be considered as part of the integrated resource management process, and their execution must be based on local objectives.

Figs. II-19 thru II-25 illustrate the relative occurrence of conifer species and associated disease pests sampled by Schmitt et al (1991) in stands representative of the forested acres on the Wallowa-Whitman National Forest. Percent of basal area affected by disease pests is shown for grand fir, Douglas-fir, ponderosa pine, Engelmann spruce, western larch, lodgepole pine, and subalpine fir, respectively. Relative occurrence of these pests is believed similar for the other two Blue Mountains National Forests.

Diseases of Grand Fir in Managed Stands on the Wallowa-Whitman National Forest



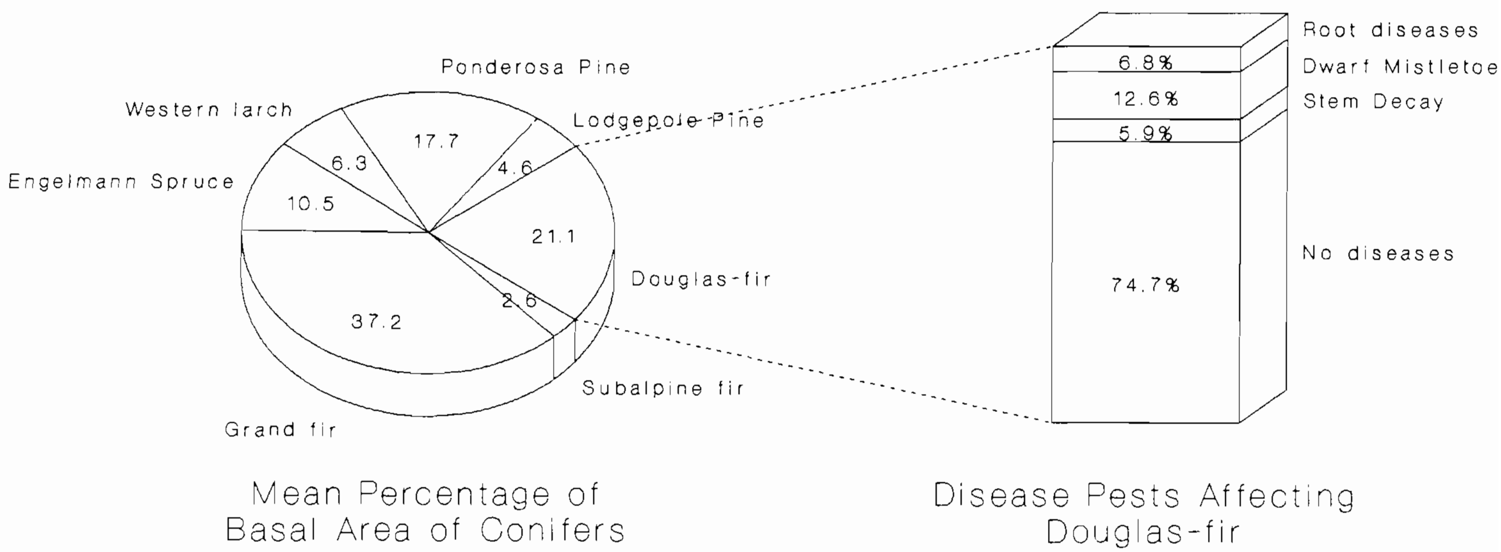
Mean Percentage of Basal Area of Conifers

Disease Pests Affecting Grand Fir

From C. Schmitt et al (1991)

Figure II-19

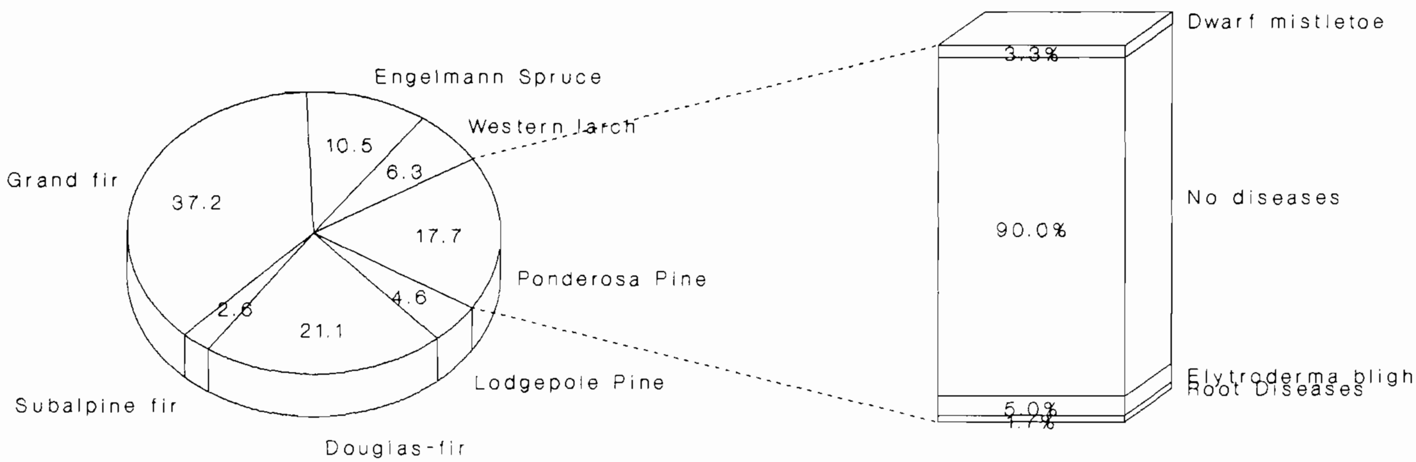
Diseases of Douglas-fir in Managed Stands on the Wallowa-Whitman National Forest



From C. Schmitt et al (1991)

Figure II-20

Diseases of Ponderosa Pine in Managed Stands on the Wallowa-Whitman National Forest



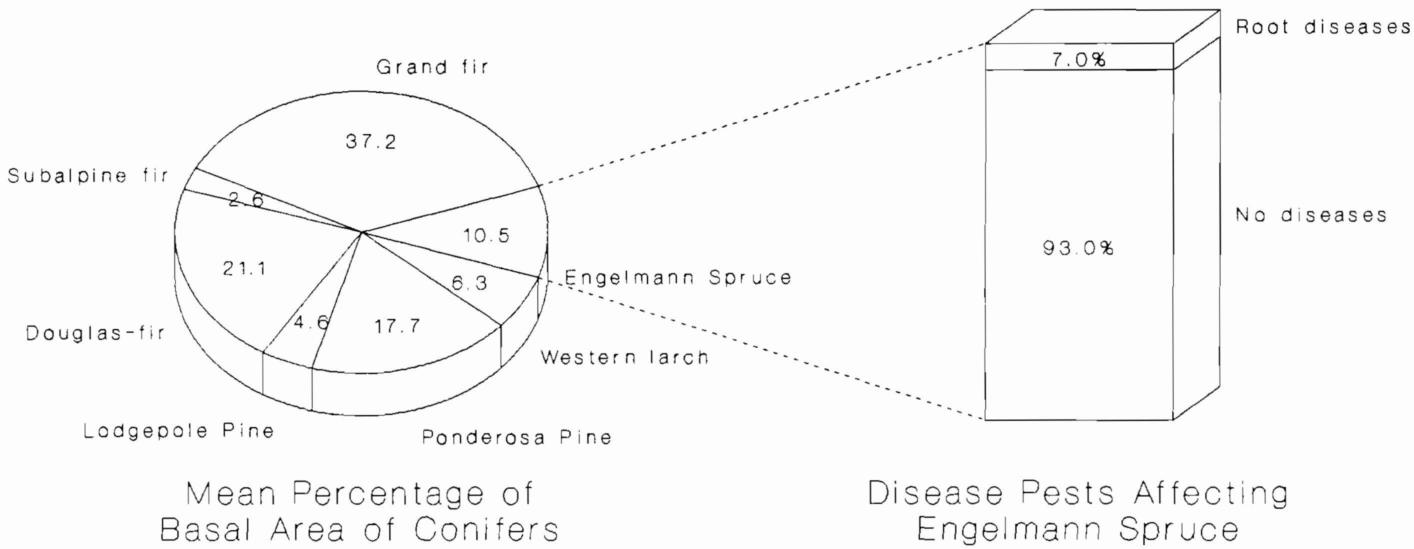
Mean Percentage of Basal Area of Conifers

Disease Pests Affecting Ponderosa Pine

From C. Schmitt et al (1991)

Figure II-21

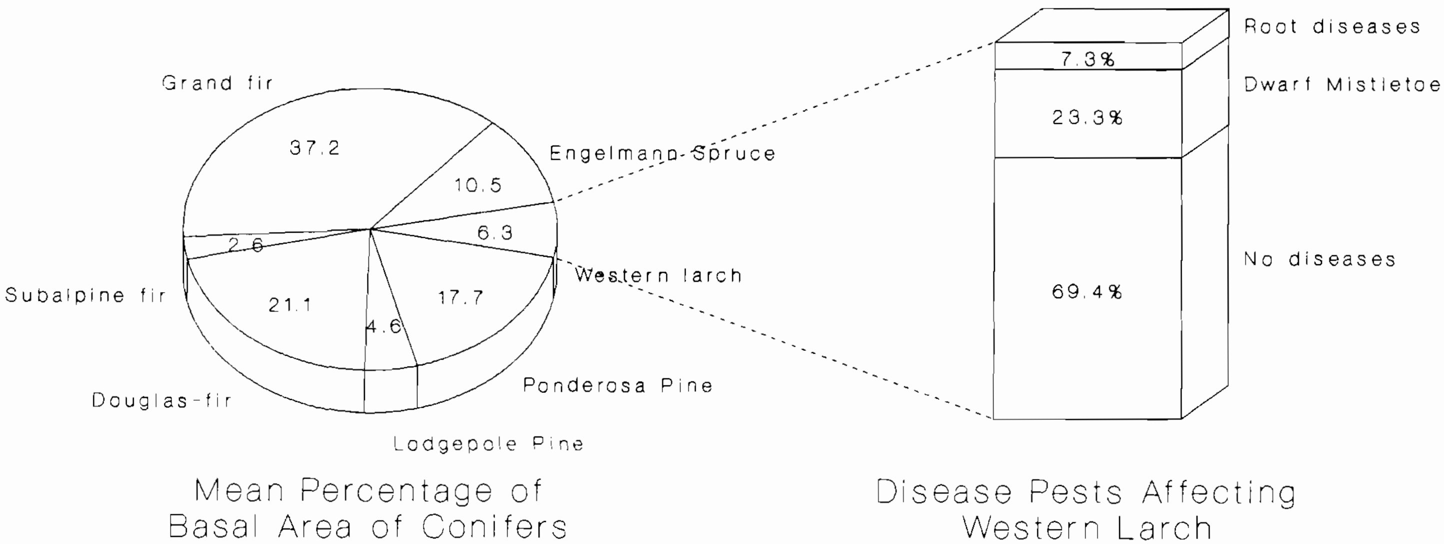
Diseases of Engelmann Spruce in Managed Stands on the Wallowa-Whitman National Forest



From C. Schmitt et al (1991)

Figure II-22

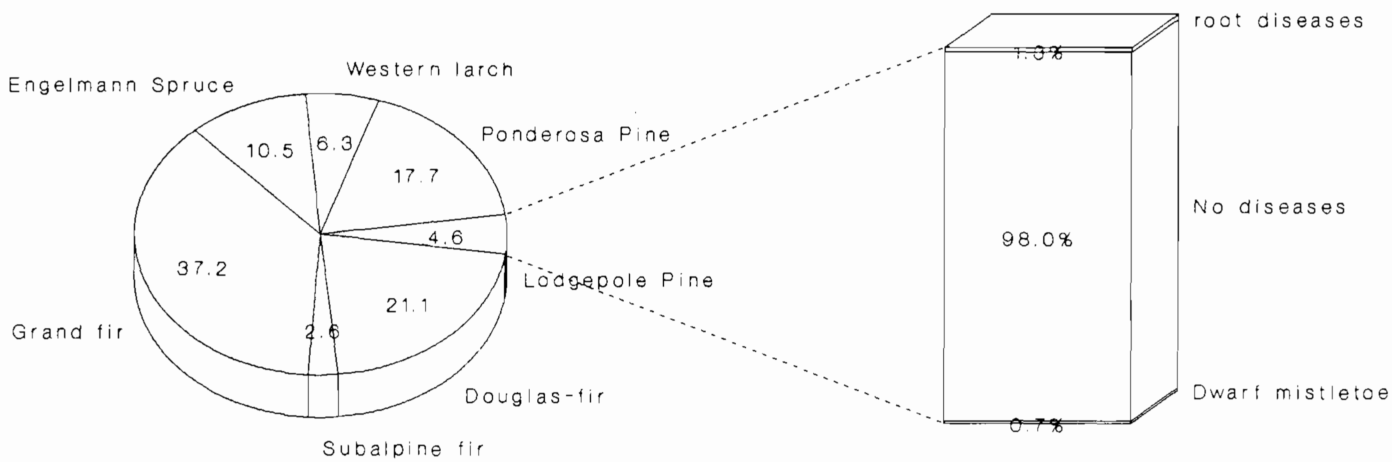
Diseases of Western Larch in Managed Stands on the Wallowa-Whitman National Forest



From C. Schmitt et al (1991)

Figure II-23

Diseases of Lodgepole Pine in Managed Stands on the Wallowa-Whitman National Forest



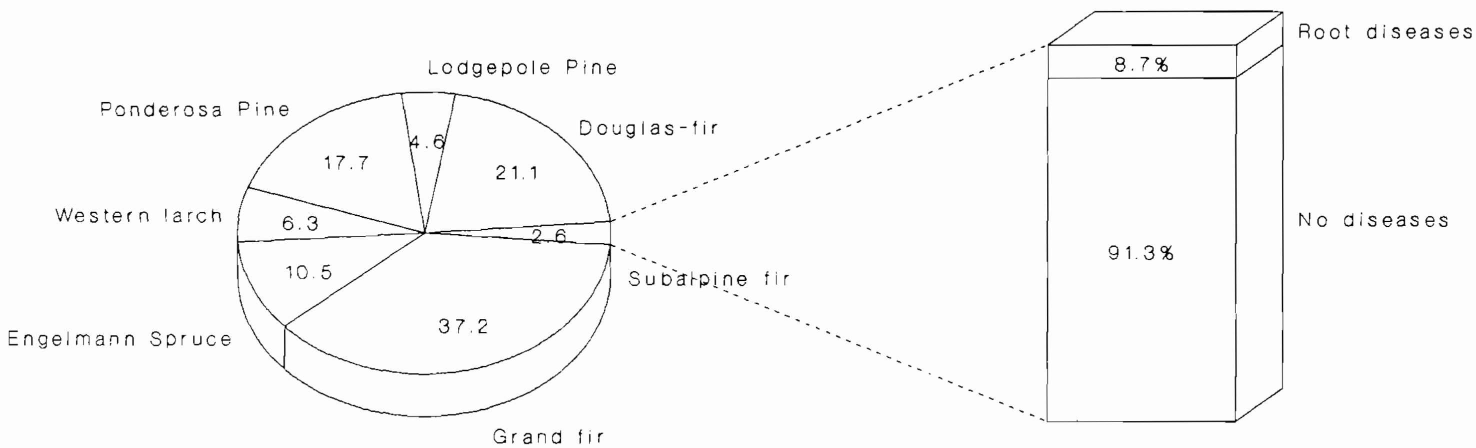
Mean Percentage of Basal Area of Conifers

Disease Pests Affecting Lodgepole Pine

From C. Schmitt et al (1991)

Figure II-24

Diseases of Subalpine Fir in Managed Stands on the Wallowa-Whitman National Forest



Mean Percentage of Basal Area of Conifers

Disease Pests Affecting Subalpine Fir

From C. Schmitt et al (1991)

Figure II-25

Laminated Root Rot

Laminated root rot is caused by the fungus, *Phellinus weirii*. This root disease causes severe damage in affected mixed conifer stands. Most of the disease's impact results in direct tree mortality and the losses associated with infected portions of stands being under-productive. Growth loss also occurs, especially in large trees that can be infected for decades before they are killed or windthrow.

Hosts and Communities:

There are significant differences in susceptibility among conifers: Douglas-fir, white fir and grand fir are highly susceptible (readily infected and killed); western larch, subalpine fir and Engelmann spruce are intermediately susceptible (often infected but seldom killed); pines are tolerant (seldom infected and almost never killed); hardwoods are immune (Filip and Schmitt 1979; Hadfield 1985).

Laminated root rot probably occurs in all communities that have a component of highly susceptible species. It follows then that damage and spread are highest in stands dominated by highly susceptible species. Susceptible shade tolerant species dominate in late seral stages of most CW communities and all stages of CD communities. Williams and Leaphart (1978) found that in northern Idaho laminated root rot was most common in Douglas-fir - ninebark (Psme/Phma) and grand fir - pachistima (Abgr/Pamy) habitat types. Subalpine fir (Abla) communities had the lowest frequency of *P. weirii*.

Disease Spread:

P. weirii rarely spreads by spores. Spread occurs most often when mycelium on the exteriors of roots crosses from infected to uninfected roots via grafts or contacts. The fungus will not grow directly through soil. The fungus remains viable in buried woody tissue for up to 50 years, allowing it to remain on a site for successive generations, surviving on live and dead host material. It is thus considered a disease of the site.

Sites infected with *P. weirii* continue to experience losses as long as highly susceptible trees are stand components on a site. If susceptible species regenerate the site, either naturally or artificially, it takes 15 to 20 years for regeneration to become infected. Upon infection, young trees soon exhibit crown symptoms and are killed. The fungus spreads along root systems, enlarging centers at an average of about 1 foot per year. Older trees that become infected take much longer to display crown symptoms and die. Typically, disease centers regenerate to vegetation characteristic of the plant community and size of the opening. Usually, some component of highly susceptible species regenerates and is eventually killed; stocking is almost always below normal. Often, some portion of intermediately susceptible and tolerant species make up the regeneration within disease centers. These trees may become infected but most will survive. Damage to these trees is highest when they grow in association with highly susceptible species.

Stand Conditions:

Williams and Marsden (1982) concluded that frequency of root diseases in northern Idaho was directly related to relative occurrence of Douglas-fir and grand fir. They also found that root disease frequency was inversely related to elevation, and higher probability of root disease was associated with increased slope. There is no evidence that conditions such as soil type, topography, or site disturbance directly influence incidence of laminated root rot. Stand vigor seems to have no influence on susceptibility to damage.

History:

The severity of damage has been increased by events that have converted stands on affected sites to a higher component of susceptible species:

-Many decades of fire control have increased the host complement on sites where those species are climax.

-Partial cutting has opened up canopies gradually, without significant soil disturbance, and has favored shade tolerant species.

-Selective harvesting of ponderosa pine has favored stand replacement by Douglas-fir and true firs.

-Overstory removal cuts in root diseased stands have resulted in conversion to highly susceptible Douglas-fir and true fir dominated stands on those sites.

Management Options:

Control of laminated root rot is most easily accomplished by converting stands on affected sites to a less susceptible condition. Management of the least susceptible species on diseased sites is usually the most effective method of reducing current and future losses.

The Western Root Disease Model (WRD) (McNamee et al 1989; Stage et al 1990),can be used to compare different management alternatives and various scheduling options to maximize resource outputs and meet resource goals. Simulating management of less susceptible species on root diseased sites will provide data for site-specific analysis. To properly use the model, stand exam data relating to trees killed and infected by root disease, as well as area within root disease centers, needs to be collected.

Options including stump removal and stump fumigation are potential control techniques but have very limited applicability. Recommended treatment in mixed conifer stands is as follows:

1. Map laminated root rot areas during stand examination or reconnaissance. Include a permanent record in a GIS database. If Western Root Model simulations are planned, assure that supplemental data are collected.

2. Plan regeneration harvest with the objective of replacing the existing stand with one that is fully stocked with species that are immune, resistant, tolerant, and intermediately susceptible. Regeneration harvests including residual seed trees of larch, lodgepole pine, ponderosa pine, western white pine, and spruce should be considered if these species are available. If seed trees are inadequate or nonexistent, planting with a mix of these species is recommended. In most cases, larch and spruce, intermediately susceptible species, will survive at acceptable levels within disease centers.

3. Treatment areas should include entire disease centers or encompass two or more smaller centers. Usually it is best to treat entire units similarly.

4. During stand improvement entries, remove those naturally regenerated species that are highly susceptible, since they will tend to perpetuate infection on the site.

5. Consider reducing rotation length if losses become unacceptable.

Risk Rating:

The Western Root Disease Model (WRD) can be accessed through the Blue Mountain PROGNOSIS stand simulation model (Stage 1973). Effects of laminated root rot on stand growth and yield under various management situations can thereby be assessed.

Occurrence:

Laminated root rot is known to occur on the Heppner, Pomeroy, and Walla Walla Districts (UMA), and the La Grande, and Wallowa Valley Districts, and the Hells Canyon NRA (WAW). We know of no laminated root rot on the Malheur NF. Incidence is believed most prevalent on the Pomeroy and Walla Walla Districts. A large portion of the Tupper Spring area (T6S, R27E, sec. 3) on the Heppner RD (UMA) is exceptionally severely infected by laminated root rot.

Laminated root rot is native to the Northwest. In old growth stands it has mostly caused buttrot. Younger stands of susceptible trees are more commonly impacted by mortality. Mortality in regeneration appears quickly, usually within 5 to 8 years. Disease centers become apparent when a stand reaches 20 to 40 years in age. Rates of mortality in individual affected stands can be 2 to 4 percent, per year, for susceptible species. After 80 to 120 years, stocking and volume can be reduced by 50 to 75+ percent. Current Forest Inventory and Stand Examination data are not believed to be very accurate with regard to root disease information; thus losses, both in acres affected and volume lost, are not known.

Appendix F-1 includes the mean estimates of occurrence of laminated root rot by management allocation based on questionnaire responses. Timber, and timber and wildlife allocations are believed to have the highest occurrence at low, medium and high levels of intensity. Little difference is believed to exist between incidence in the Douglas-fir and grand fir plant community series (Appendix F-3).

Effects:

Most references to impacts attributed to laminated root rot are directed to timber-related values. Recreation sites can also be seriously affected by occurrence of laminated root rot. No known recreation sites currently exist on *P. weirii*-infected sites in the Blue Mountains.

Timber resources are impacted by mortality, growth loss of infected trees, and loss of productivity on infected sites. Such impacts can be considered to affect long term site productivity (Miller et al 1989). When stands are regenerated, additional costs may be incurred in order to fully stock the treated sites with resistant or less-susceptible species. In some areas, stump removal costs have been incurred where species manipulation was not a viable option. Regenerated stands may need to have one or two thinnings to remove the natural regeneration of susceptible species. Finally, additional time is required to evaluate disease incidence, modify treatment prescriptions, assure on-the-ground rehabilitation is done correctly, and monitor treatment areas through time.

Occurrence of laminated root rot in recreation sites predisposes trees to failure that can damage property and result in injury or death. Recreation sites should not be developed in affected areas.

In some cases, laminated root rot can contribute to diversity by providing down material and creating openings in stands. However, spread of the disease, resulting in gradually increasing centers, and the extremely damaging effects caused in stands with a high incidence of this root disease, limit acceptance of this damage to management allocations where catastrophic losses are already taken into account.

Of the 16 Ranger Districts surveyed, those Districts identifying impacts by laminated root rot for each management allocation are shown in Appendix F. Timber and wildlife allocations were identified as being impacted most frequently by laminated root rot. Appendix F, page 6 indicates the total area estimated to be impacted by laminated root rot for each management allocation. Very small amounts of land are believed to be affected in all allocations.

The following example (Fig. II-26) of the effects of laminated root rot is based on 100-year PROGNOSIS model simulations of two data sets (all trees uninfected and some trees infected) combined with actual stand data. The uninfected simulation portrays growth of the existing stand with the effects of root disease removed. The infected simulation portrays growth of the same existing stand with laminated root rot infection parameters. All other tree, stand, and stocking data at the beginning of the simulations are identical for each simulation.

Current existing parameters:

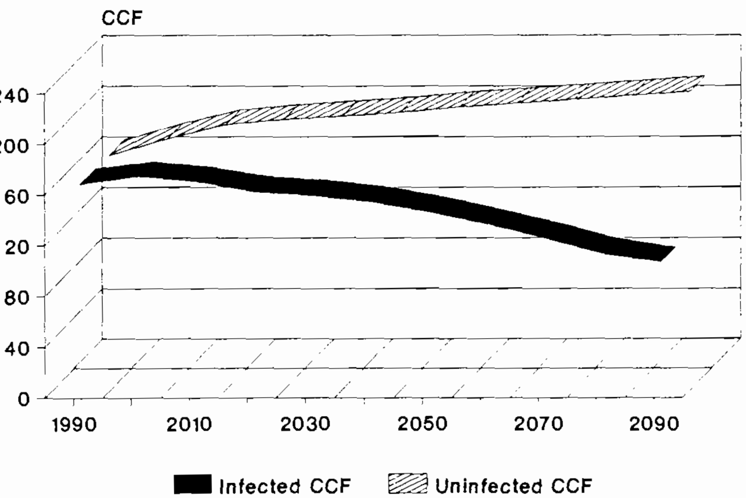
Stand 0012; Compartment 6001; La Grande RD (WAW)

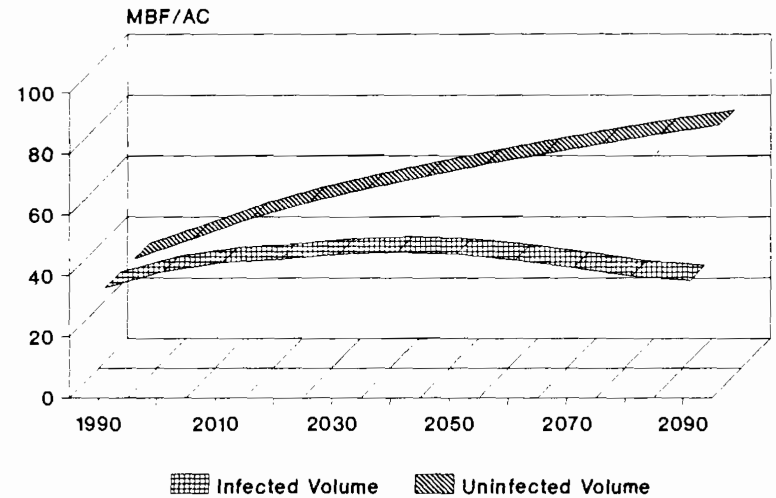
Species composition by stems	
grand fir	63%
Douglas-fir	17%
western larch	12%
Engelmann spruce	7%
subalpine fir	1%
Trees per acre -	281
Basal area -	234
Crown Competition Factor-	163
Plant Community -	CW-S2-11
Elevation -	5200 ft.
Stand area -	23.0 ac.

Root disease data for infected simulation:

Area of stand in root disease centers -	5.0 ac.
Number of disease centers -	8

PROGNOSIS Growth Simulation With Western Root Disease Extension Modeling Effects of Laminated Root Rot





Stand 0012
Compartment 6001
LaGrande Ranger District (WAW)

Figure II-26

Armillaria Root Disease

Armillaria root disease is caused by the fungus, *Armillaria ostoyae*. This is one of the most common and damaging root disease in the Blue Mountains. In active disease centers, trees are often killed outright, but when this is not the case, infected trees are frequently weakened and attacked by secondary pests. Considerable geographic variability exists in the virulence of the fungus and in relative host susceptibility.

Hosts and Communities:

All conifers can be infected by *A. ostoyae*, but grand fir is among the most susceptible hosts. Western larch and lodgepole pine are usually least affected. Engelmann spruce can be damaged when associated with susceptible species or where the disease is especially virulent. Douglas-fir and ponderosa pine susceptibilities vary widely; they can be very susceptible or display considerable resistance. Site-specific evaluations need to be made in order to determine disease virulence and relative susceptibility of different species.

There is some evidence that disease incidence varies by plant community. Highest incidence has been observed in the wet plant communities (CE and wet CW), with less occurring in the dry plant communities (dry CW, CD and CP)(McDonald et al 1987). Successional stages most likely to be damaged are late seral stands where susceptible hosts are dominant.

Disease Spread:

A. ostoyae is an efficient saprophyte that frequently colonizes roots or stumps of dead trees. In some situations Armillaria root disease severity is exacerbated following selective cutting because cut stumps are colonized and later become foci of root disease centers. Stumps are usually colonized by fungus in the soil. Airborne spores of *A. ostoyae* also colonize stumps, but less frequently than by root contacts and soil-borne mycelia. The fungus can spread through the root systems of infected trees and stumps both through woody tissue and fungal structures called rhyzomorphs that grow both under the bark and on the exteriors of root systems. Rhyzomorph spread can be transmitted up to 6 feet through the soil between infected and uninfected roots. Upon infection however, some trees successfully occlude the fungus, resulting in little decay or root colonization.

Stand Conditions:

Stands that have been disturbed in association with partial cutting are generally more severely impacted by Armillaria root disease. Soil compaction and displacement associated with ground-lead yarding, lower bole and root damage, and other associated stresses can result in increased Armillaria root disease damage. Creation of numerous large stumps can result in excessive levels of inoculum that subsequently increase disease levels. These developments, coupled with the effects of fire exclusion and a high component of susceptible species such as grand fir, can result in epidemic disease levels.

Some unmanaged stands are also known to be excessively damaged by this root disease. Recent changes in stand character, such as increased stocking and invasion of fir on pine sites due to fire exclusion, may explain this occurrence.

History:

Occurrence of Armillaria root disease and its associated impacts are believed to be on the increase in the Blue Mountains. This is because changes in stand composition and structure have made stands more susceptible to damage.

-Many decades of fire control have increased the susceptible host complement on sites where those species are climax

-Partial cutting has opened up the canopies gradually, without significant exposure of mineral soil, and thus has resulted in sites favoring shade tolerant species.

-Selective harvesting of ponderosa pine has favored stand replacement by Douglas-fir and true firs.

-Overstory removal cuts in root diseased areas have resulted in conversion to highly susceptible Douglas-fir and true fir-dominated stands on those sites.

-Exclusion of fire has resulted higher stocking and increased stress; this becomes most apparent during periods of drought-increased mortality.

Management Options:

Most effective and practical treatments for minimizing damage by Armillaria root disease include: Increasing host vigor, managing for disease-tolerant species, and minimizing inoculum on the site.

The Western Root Disease Model can be used to compare different management alternatives and various scheduling options to maximize resource outputs and meet resource goals. Simulating management of less susceptible species on root diseased sites will provide data for site-specific analysis. To properly use the model, stand exam data relating to trees killed and infected by root diseases, as well as area within root disease centers, needs to be collected.

In pole- to small sawtimber-sized stands consider the following:

1. Map locations of Armillaria root disease centers and store in a permanent GIS database. Mapping and accurate root disease identification can be incorporated into stand examinations by giving examiners supplemental insect and disease identification training. If the Western Root Disease model is used to simulate management alternatives, assure that additional needed information is collected.

2. Patch cut severely infected portions of stands having inadequate stocking of crop trees and regenerate with a mix of species least susceptible to damage. Use natural regeneration as much as possible.

3. Thin healthy portions of stands as normally prescribed. Do not leave crop trees which are susceptible to root disease damage within 25 feet of root disease-killed or -symptomatic trees. Favor those species least affected as crop trees.

4. Avoid frequent salvage entries.

In large sawtimber-sized stands consider the following:

1. Map locations of Armillaria root disease centers and store in a permanent GIS database.

2. If possible, treat entire centers, including a buffer of 50 feet beyond trees showing last visible indicators of infection.

3. Use a regeneration silviculture system; residuals of less-susceptible species should be retained for seed sources if possible. Naturally regenerated trees are more resistant to attack than those that are planted. If needed, underplant with disease tolerant species to assure diversity and adequate stocking.

4. In some situations inoculum removal may be a viable option. This involves stump and root removal with heavy equipment and has been done on sites where site adapted non-susceptible species do not exist.

Risk Rating:

The Western Root Disease Model (Stage et al 1990) can be accessed through the Blue Mountain variant of the PROGNOSIS stand simulation model. Effects of Armillaria root disease on stand growth and yield under various management situations can thereby be assessed.

Occurrence:

Armillaria root disease is known to exist on all Districts on the Umatilla, Malheur, and Wallowa-Whitman National Forests. Extensive areas of infection are known to exist on the Walla Walla Ranger District (UMA), and Unity Ranger District (WAW). Stands surveyed on the Wallowa-Whitman National Forest in 1986 and 1987 indicated infection rates of 1.9 and 2.4 percent of the total basal area for all conifer species for CP/CD, and CW sites, respectively. These figures are believed to be representative throughout stands in the Blue Mountains (Schmitt et al 1991). Forest Inventory and Stand Examination data are not believed to be very accurate with regard to root disease information; therefore, estimates of disease occurrence and resource losses originating from these sources are not believed to be accurate.

Appendix F-1 includes the mean estimates of occurrence of Armillaria root disease by management allocation based on questionnaire responses. Riparian, and timber and wildlife allocations were identified as having 4 and 1.8 percent of the acres being impacted by severe intensities of Armillaria, respectively. All other allotments are believed to be impacted by low and medium intensities of Armillaria with riparian, timber and wildlife, wildlife, and viewshed allocations having the highest incidence. All plant association series are impacted; most at the low and medium intensities (Appendix F-3).

Effects:

Armillaria root disease is the second most damaging root disease on the Wallowa-Whitman National Forest and probably has a similar ranking throughout the Blue Mountains (Schmitt et al 1991). Most impact in the past has been described in terms of the timber resource. Losses occur to other resources where extensive mortality is unacceptable. Recreation sites, visual corridors and viewsheds, and some riparian communities can be adversely affected.

Mortality, growth loss, defect, and loss of productivity of affected sites are impacts that are primarily damaging to timber resource values. Most affected sites will probably be impacted by reduction in site productivity over many years. In terms of relative susceptibility, even the least affected species will experience some level of mortality. Planted trees will be more susceptible than naturals, and even the most resistant species (western larch and lodgepole pine) may not be adapted to the site or sufficient seed sources may not be available. Many affected sites have been predisposed to Armillaria by soil compaction and displacement and will also experience impaired productivity.

Costs for maintaining full stocking of those species least impacted by Armillaria will be higher than stocking costs in unaffected stands. Stump removal has been done where species manipulation (i.e. management for resistant species) is not a viable option. Regenerated stands may need to have one or two thinnings to remove natural regeneration of susceptible species. Additional time and resources are needed to evaluate disease incidence, modify treatment prescriptions, ensure that treatment is correctly done, and monitor treatment areas through time.

Armillaria root disease can occasionally damage trees in recreation sites. Such trees are hazardous if they are predisposed to failure and grow near a frequently occupied site. Soil compaction in high use areas may be a contributing factor to occurrence of root disease. Large root disease centers occur when Armillaria is especially virulent. The development of new recreation sites in such areas should be avoided.

There can be considerable short-term impacts to various resources in treatment areas where objectives are to reduce Armillaria damage and restore site productivity and Forest Health. Frequently, large disease centers and buffers exceed acreage limitations for created openings. So it may be necessary that large treatment units be accepted in order to meet long-term goals.

In some cases Armillaria root disease can contribute to diversity by providing down material and creating openings in stands. Endemic levels of Armillaria, where mortality is scattered and not forming large centers, may be acceptable in some management allocations and even desirable in others. Excessive spread of the disease, resulting in gradually increasing centers, and the extremely damaging effects caused to stands with a high incidence of this root disease, limit acceptance of high levels of damage to management allocations where catastrophic losses are already taken into account.

Of the 16 Ranger Districts surveyed, those Districts identifying impacts by Armillaria root disease for each management allocation are shown in Appendix F. Timber and wildlife allocations were identified as being impacted most frequently by Armillaria root disease. Appendix F, page 6 indicates the total area estimated to be impacted by Armillaria root disease for each management allocation. About 23,000 acres are believed infected in wildlife allocations and 10,000 acres infected in timber and wildlife allocations. Very small amounts of land are believed to be affected in other allocations.

The following example (Fig. II-27) of the effects of Armillaria root disease is based on 100-year PROGNOSIS model simulations of two data sets (all trees uninfected and some trees infected) combined with actual stand data. The uninfected simulation portrays growth of the existing stand with the effects of root disease removed. The infected simulation portrays growth of the same existing stand with armillaria root disease infection parameters. All other tree, stand, and stocking data at the beginning of the simulations are identical for each simulation.

Current existing parameters:

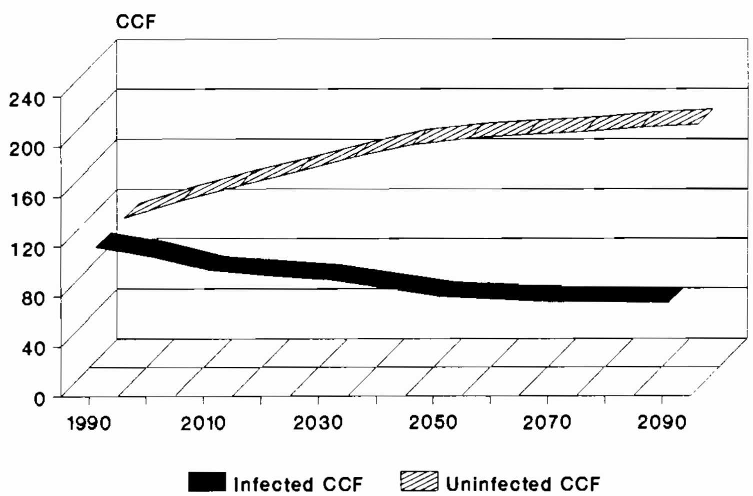
Stand 0009; Compartment 6001; La Grande RD (WAW)

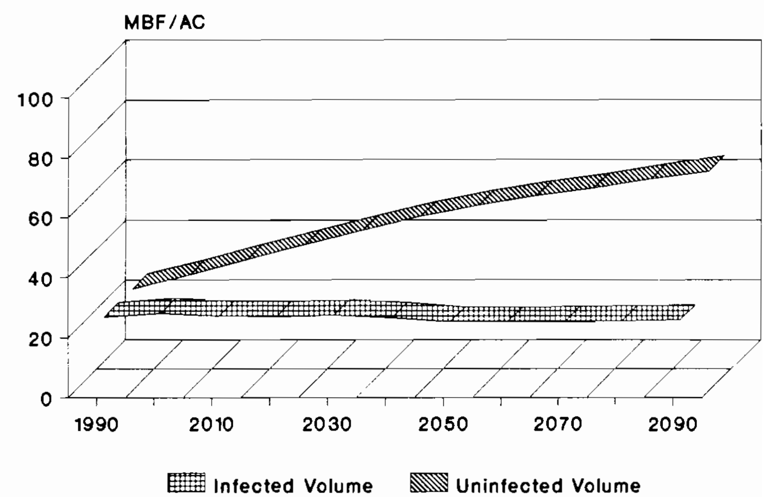
Species composition by stems	
grand fir	50%
Douglas-fir	23%
western larch	21%
Engelmann spruce	6%
Trees per acre -	503
Basal area -	160
Crown Competition Factor -	114
Plant Community -	CW-S2-11
Elevation -	5200 ft.
Stand area -	16.0 ac.

Root disease data for infected simulation:

Area of stand in root disease centers -	8.0 ac.
Number of disease centers -	9

PROGNOSIS Growth Simulation With Western Root Disease Extension Modeling Effects of Armillaria Root Disease





Stand 0009
Compartment 6001
LaGrande Ranger District (WAW)

Figure II-27

Annosus Root Disease

Annosus root disease is caused by the fungus, *Heterobasidion annosum*, also known as *Fomes annosus*. This disease causes growth loss, root and butt rot, uprooting, and mortality of infected trees.

Hosts and Communities:

All conifers can be infected by *H. annosum*, but grand fir, white fir, subalpine fir, and in some areas ponderosa pine, are most susceptible to infection and damage. However, pine and fir are affected by different strains of the fungus and spread does not occur between them.

Annosus root disease is most commonly found damaging firs in the CW and CE vegetation series, especially in later successional stages when firs dominate the vegetation. Ponderosa pine is usually damaged in communities at the dry end of the CP vegetation series, and it is damaged most extensively in the early seral stage.

Disease Spread:

Heterobasidion annosum infects its hosts two ways: By airborne spores germinating and colonizing freshly exposed wood, and by fungal growth across root grafts and contacts between diseased and healthy roots.

Infection of freshly cut stumps by *H. annosum* spores is the most common way that new root disease centers develop. Mycelium from germinating spores grow into stumps, colonize the woody tissues, and eventually spread through the root systems. Mycelium can grow on the exterior of colonized roots, spreading between roots at grafts and contacts; it cannot grow through the soil. Stump infection is most common in the spring and autumn in dry pine (CP) plant communities. In true fir (CW) stands, infection also occurs throughout the summer. Stump infection rates of 89 percent have been found in 5 to 10 year old grand fir stumps on the Walla Walla Ranger District (UMA) (Filip et al 1990), and almost all annosus root disease in pine and grand fir stands has been associated with large stumps (18" in diameter and larger). Stumps created during precommercial thinnings may be colonized by the fungus, but such activity seldom results in disease center development. However, there is evidence that annosus root disease can become established in subalpine fir stands through stumps as small as 10 inches in diameter.

Wounds to susceptible hosts are very frequently colonized by *H. annosum* (Filip 1991). Wounds usually result in decay of individual wounded trees, with large wounds resulting in more extensive decay than smaller wounds. Wounds less than 6 years old generally have little or no associated decay (Aho 1974). Wounds and resulting infection are compartmentalized and sometimes result in the fungus causing extensive decay, but in this type of infection, the fungus does not end up growing as ectotrophic mycelium on the exterior of roots. Thus, root disease center development is uncommon around live wounded trees.

Stand Conditions:

In unmanaged stands, annosus root disease usually occurs at low levels. But stands that have had multiple partial cut entries tend to have a higher occurrence, especially in mixed conifer stands where true fir has been cut. However, most stands in the Blue Mountains have not had true fir removed prior to 1970. Earlier entries were usually for pine, Douglas-fir, and larch. Ponderosa pine stands on marginal CP sites that have had a history of selective or regeneration harvesting can have substantial annosus root disease. But in CW stands, *H. annosum* did not become established until firs were cut.

History:

Annosus root disease and its associated damage is definitely increasing in Forests of the Blue Mountains. Exclusion of periodic ground fire has increased the proportion of highly susceptible true firs. Partial cutting has favored development of shade tolerant understory. Again, this is mostly true firs, rather than seral pines and larch that require more stand opening to become established and survive. Creation of true fir stumps and wounds resulting from partial cut entries have led to stand infection. Damage is starting to occur in some stands where true fir was harvested in the past. In the future, annosus root disease is expected to affect stands where stumps were not treated.

Management Options:

In true fir stands avoid frequent commercial entries. Trees that are wounded should be removed. In harvest units where true fir will be managed in the future, treat stumps 12 inches or larger in diameter with borax as specified in C-Provision C6.412. On high hazard pine sites, borax stump treatment should be required. Stump removal is an option that may be viable in certain situations. Promote diversity by managing a mix of species including major components of seral pines, larch, and less susceptible Douglas-fir and spruce in applicable CW communities. Using regeneration harvest techniques, establishment of seral pines and larch should be encouraged on affected or high hazard sites. Where applicable, firs should be managed for rotations of less than 120 years, especially in stands that have been disturbed.

Forest direction on the Umatilla National Forest since January 24, 1990, has been to treat all true fir stumps in harvest units where firs will be managed in the future. Districts on the Wallowa-Whitman and Malheur National Forest's have been specifying borax treatment in timber sale contracts since 1989.

Risk Rating:

The Western Root Disease Model can be accessed through the Blue Mountain PROGNOSIS stand simulation model. And even though Annosus root disease is not included in the current version of the Western Root Disease model. A new version of the model is being built that includes annosus root disease; this is expected to be released in 1991 (Shaw et al 1989).

Occurrence:

Annosus root disease is wide-spread, occurring on all Forests in the Blue Mountains. Current damage is highest in true fir stands with a history of fir removal more than 20 years ago. It is expected that in the future this root disease will become more damaging. Stands surveyed on the Wallowa-Whitman National Forest in 1986 and 1987 indicated infection rates of 0.9 and 3.2 percent of the total basal area for all conifer species for CP/CD and CW sites, respectively. These figures are believed to be representative of all managed stands in the Blue Mountains (Schmitt et al 1991).

Appendix F-1 includes the mean estimates of occurrence of Annosus root disease by management allocation based on questionnaire responses. Severe intensities are in the old growth (12.5% of area), timber and wildlife (11.7%, wildlife (20%), and riparian (10%). All allotments are believed impacted by low, medium, and high intensities of annosus. Most occurrence is at the low and medium intensities.

Plant association series impacted by annosus include subalpine fir, mountain hemlock, and grand fir. Occurrence of high and severe intensities is most common in the subalpine and grand fir series (Appendix F-3).

Effects:

Annosus root disease is the most common root disease on the Wallowa-Whitman National Forest and probably throughout the Blue Mountains as well (Schmitt et al 1991). It is most damaging to true firs, and in the past, has been discussed primarily in terms of impact on timber resources and recreation sites. Annosus-caused mortality, oftentimes associated with fir engraver beetles, is striking in view-sheds where partial cutting has occurred in the past.

Mortality, growth loss, defect, and loss of productivity on affected sites are impacts that primarily affect timber resource values. Use of partial cutting, which has led to initial infection as well as conversion of mixed conifer stands to higher components of fir, needs to be restricted to plant communities and management allocations where this disease is not a problem or its effects are acceptable.

Conversion of affected stands to a healthy condition requires silvicultural strategies that allow sub-stantial regeneration of seral species. Such treatments are usually complete and successful in mixed conifer communities since host susceptibility is largely limited to true firs. Unfortunately, areas affected are often quite extensive and complete treatment will eventually require conversion of susceptible host types that have been partially cut in the past. Since these stands in their present condition provide the best short term big game cover values, effects of treatment will need to be mitigated.

Recreation sites located in stands of true fir are frequently affected by insects and diseases in ways which can result in hazard. Decay and root disease caused by *H. annosum* is especially hazardous. Use of borax is required in recreation sites by Manual direction (FSM 2331.31) to minimize introduc-tion of new disease centers.

In some cases, annosus root disease can contribute to diversity by providing down material and creating openings and scattered dead trees in stands. Common occurrence of this root disease in mixed conifer stands, resulting in gradually increasing centers of mortality, limits acceptance of this damage to management allocations where the value of timber resources is of lesser importance and extensive mortality is acceptable.

Of the 16 Ranger Districts surveyed, the number of Districts identifying impact by annosus root disease for each management allocation is shown in Appendix F-5. Timber and wildlife allocations were identified as being impacted most frequently by annosus root disease. Appendix F-6 indicates the total area estimated to be impacted by annosus root disease for each management allocation. About 60,000 acres are believed affected in timber and wildlife allocations. Low acreage is believed affected in other allocations.

Black Stain Root Disease

Black stain root disease is caused by the fungus, *Ceratocystis wageneri*, also known as *Ophiostroma wagenerii* var. *ponderosum*. This root disease causes a vascular wilt rather then wood decay. Affected trees are killed rapidly and mortality is often associated with bark beetles and wood borers. This root disease was unrecognized in the Blue Mountains until recently.

Hosts and Communities:

Conifers found to have been infected by *C. wageneri* include Douglas-fir, ponderosa pine and grand fir. Lodgepole pine has also been affected in the West, but not in the Blue Mountains. Observations in affected stands throughout the Northwest suggest that more than one strain/species of this pathogen exists and different conifers will be susceptible in different stands. This probably explains the differences in host types and relative susceptibility noted for this root disease in the Blue Mountains.

Because occurrence of this root disease is at the same time both uncommon and disparate among a variety of plant communities, researchers are uncertain as to whether it is more common in certain communities or seral stages: Ponderosa pine has been found to be infected in dry CP communities in early and mid seral stages; pine has also been infected in mixed conifer (CW) communities associated with larch, grand fir, douglas-fir, and lodgepole pine; grand fir was infected and killed at one (CW) site; and Douglas-fir was found to be infected on a CD site associated with uninfected ponderosa pine.

Disease Spread:

Long distance spread of *C. wageneri* involves insect vectors. While these vectors have never been studied in eastern Oregon, they are probably similar to those vectors identified in western Oregon and Washington which involved root-feeding beetles (*Hylastes* sp.) and weevils (*Steremnius* sp. and *Pissodes* sp.): Microscopic fruiting bodies of *C. wageneri* grow in the galleries of these insects and the spores that are produced adhere to their bodies. These insects disperse and commonly feed on the roots of stressed low-vigor trees. Often-times these initially-attacked trees are at stand edges or are adjacent to roads, fire lines, skid trails, etc. Insects vector the fungus through roots and the root collar of hosts when they attack and feed on these trees.

Once *C. wageneri* is established in its host, it will grow a short distance up the bole and down through the root system. The fungus will spread to adjacent trees via root grafts, contacts, or even a short distance through the soil. Spread of the infection in both individual trees and disease centers is rapid. Disease centers have been monitored in western Oregon that are expanding at rates of 5 feet per year. Susceptibility of hosts to black stain root disease (spread via roots) does not seem to be affected by tree vigor. Also, conditions or activities that favor insect populations, such as creation of stumps through thinning, tend to favor spread of the disease.

Stand Conditions:

There is evidence in some situations that management-related disturbance and site conditions that stress trees tend to increase stand susceptibility to black stain root disease. Soil compaction and displacement, wounding of residuals, and fresh stumps associated with logging have been found to predispose stands to this root disease in other areas of the West.

History:

Very little is known about the occurrence and damage associated with black stain root disease in the past. It is believed to have been very minor. Some current management practices are known to increase stand susceptibility, and therefore, the potential for damage to result from this root disease. Impacts are likely to increase in the future.

Management Options:

Management recommendations for Blue Mountain stand conditions have not been developed or tested. Some recommendations for West Side stands are not applicable here. For example, recommendations to time thinning to reduce damage or risk to mountain pine and Ips beetles in ponderosa pine stands may promote black stain root disease. Stands are considered to be susceptible if they are similar in age and species composition to a nearby stand with confirmed black stain root disease. Pest specialists should be consulted for site-specific evaluations where this disease is of concern. Some general recommendations to minimize hazard of black stain root disease in susceptible stnads follow:

1. Minimize site and stand disturbance by (Cobb 1988):
   a. Avoiding soil compaction and displacement,
   b. using cable yarding systems as much as possible, and
   c. minimizing damage to trees along roadsides during road maintenance.

2. Promote stand diversity through:
   a. Regenerating high hazard sites with species that include nonhosts,
   b. favoring nonhosts in thinning, and
   c. managing nonhosts on stand edges and along skid trails.

3. Minimize insect vector attraction to stands by:
   a. Avoiding the need for thinning by wide spacing when planting, and
   b. avoiding thinning hosts.

4. Treatment for infested stands should include:
   a. Favoring nonhosts in centers, and
   b. clearcutting centers with a buffer zone around centers to stop root-to-root spread of the pathogen.

Occurrence:

Black stain root disease is known to occur in stands on the Burns Ranger District, Prairie City Ranger District, and Bear Valley Ranger District (MAL); and the Wallowa Valley Ranger District (WAW). Incidence is believed to be low; although damage to affected stands can be high.

Appendix F-1 includes the mean estimates of occurrence of black stain root disease by management allocation based on questionnaire responses. Low intensities have a high perceived occurrence in wildlife (52%) and timber and wildlife (35%) allocations. These high levels of occurrence were generated from high values given in a very few responses and probably overestimate Blue Mountain-wide occurrence.

The ponderosa pine association series was also identified as having a very high level (52%) of low intensity infestation (Appendix F-3).

Effects:

Black stain root disease is not currently believed to cause extensive damage in the Blue Mountains. However, there is a growing concern that this disease is becoming more severe as a result of current management recommendations, specifically, thinning of overstocked ponderosa pine. Stress caused by soil compaction associated with ground-lead yarding and thinning, may favor spread by insect vectors and promote development of this root disease.

The complete biology, and state-of-the art management of black stain root disease in second growth and small sawlog-size ponderosa pine needs to be determined before state-of-the art management can be applied. Management strategies to reduce susceptibility to bark beetles requires stocking level control in many Blue Mountains pine stands. If this strategy results in exacerbating incidence of, and damage by, black stain, the best and most effective IPM strategy needs to be developed.

Of the 16 Ranger Districts surveyed, the number of Districts identifying impact by black stain root disease for each management allocation is shown in Appendix F-5. Timber and wildlife allocations were identified as being impacted most frequently by black stain root disease. Appendix F-6 indicates the total area estimated to be impacted by black stain root disease for timber and wildlife, and viewshed allocations; very low impacts exists. Other allocations are not believed affected.

Schweinitzii Root and Butt Rot

Schweinitzii root and but rot is caused by the fungus *Phaelous schweinitzii*, commonly known as the velvet-top fungus. It is a common cause of decay in old stands. Affected trees have butt and root decay and sometimes fail due to root decay or breakage in the lower bole during windstorms. This infection is not readily recognized in standing trees since fruiting bodies are rarely produced in any but the wettest sites. Butt swell is sometimes apparent in trees with extensive decay, but this disease seldom results in direct mortality of standing trees.

Hosts and Communities:

All conifers are susceptible to Schweinitzii-caused infection and damage, but damage is most common in Douglas-fir. Most mature and overmature stands with a Douglas-fir component contain some degree of infection. The disease is most readily recognized in the wet CW Plant Associations such as Abgr/Libo and Abgr/Acgl, where fruiting bodies are more likely found. However, observations of defective and cull material left in recent harvest units have shown that the disease commonly occurs in dry Douglas-fir communities as well.

Disease Spread:

Current research shows that *Phaeolus schweinitzii* primarily spreads through soil litter around infected trees, thereby infecting nearby hosts, usually through root tips. Once the fungus enters the root tip it remains confined to the heartwood of the root and slowly spreads into the lower butt and down through other roots. Wounds and basal fire scars also serve as infection courts. In older stands this disease occurs on individual trees or in small centers of hosts throughout stands. If infection is confirmed on one Douglas-fir, adjacent Douglas-firs are probably also infected.

Older trees may be infected for decades. Decay may be extensive on these trees, and may result in cull of harvested trees and mortality due to windbreak. Also, other pests may occasionally attack trees weakened by Schweinitzii root and butt rot and cause mortality.

Stand Conditions:

Old stands of Douglas-fir can be expected to have the highest level of defect. While tree wounds are no longer believed to be primary infection courts, wounds and fire scars have direct bearing on incidence of this disease.

History:

Schweinitzii root and butt rot is believed to have been an important part of old growth systems in the past. So younger stand structure tend to decrease the influence of this disease. In management allocations where old growth is managed or rotations are extended, Douglas-fir will continue to be damaged.

Management Options:

This disease will continue to be a concern in old existing stands and in stands managed on extended rotations. In these situations management direction should be to avoid wounding residual hosts in intermediate entries. Trees that are identified as being infected should be removed during scheduled entries. Trees infected with this root and butt rot need to be promptly removed in recreation sites and areas where falling trees might pose a hazard. This disease is not expected to be a management concern where stands are managed on rotations of less than 120 years.

Occurrence:

In the Northwest, most Schweinitzii root and butt rot occurs in stands above 4900 feet in elevation. Most mature Douglas-fir stands throughout the Blue Mountains probably have some level of infection. Since infection and resulting defect is usually hidden, damage is not determined until trees are cut.

Effects:

Damage caused by *P. schweinitzii* is highest in older stands. Mortality caused by windthrow due to this butt rot is usually at a low enough level that it tends to enhance stand diversity qualities. Losses are thus restricted to cull and defect in harvested trees. These losses are expected to decrease in time as management is focused on younger age classes.

Recreation sites can be impacted by hazard trees, especially on sites with a component of old Douglas-fir. Such infected trees are predisposed to windthrow and breakage.

In management allocations where old host trees are retained, and trees are managed for long rotations, the failure of occasional trees tends to contribute favorably to downed material and associated diversity.

Tomentosus Root and Butt Rot

Tomentosus root and butt rot is caused by the fungus *Inonotus* (*Polyporus*) *tomentosus.* Affected trees are damaged by root and butt decay that predisposes them to windthrow or breakage during wind storms. Harvested trees with extensive decay will usually have 4 to 8 feet of the butt log culled. Trees are seldom killed outright by this disease, but they may be weakened and rendered susceptible to other pests. Engelmann spruce predisposed to windthrow can serve to build up latent populations of spruce beetle (*Dendroctonus rufipennis*).

Hosts and Communities:

Engelmann spruce is the most common host of *I. tomentosus*, though Douglas-fir, ponderosa pine, lodgepole pine, and true firs are occasionally infected. Thus, tomentosus root and butt rot is most commonly associated with those sites where Engelmann spruce occur. These sites make up the CE series subalpine fir communities, and the cool, moist portion of the CW series, including the common Abgr/Libo and Abgr/Clun Plant Communities. Riparian stands frequently have a major spruce component. Spruce, a shade tolerant species, will increase in dominance in stands reaching mid to late seral stages. Most damage has been reported in older stands representing the late seral stage, but younger stands may also be affected. Incidence and severity of tomentosus root disease in young Blue Mountain spruce stands has not been investigated.

Disease Spread:

I. tomentosus spreads from tree to tree via root grafts or contacts (Lewis and Hansen 1989). Numerous, small groups of infected trees tend to occur throughout infected stands. Centers expand slowly since growth of the fungus is slow on root systems. Wounded roots are believed to be more susceptible to infection. Spore spread probably occurs also, but at very low levels. Large infected roots retain viable infection for at least 20 years, and regenerated stands become infected upon root contact with this buried inoculum.

Stand Conditions:

Tomentosus root and butt rot is believed to occur on most all sites with significant stocking of spruce, though damage is likely to be highest in older stands. Stands that have had commercial partial removal entries are likely to experience more extensive infection and damage due to the consequent wounding and disturbance incurred by such activity.

Management Options:

This disease is hard to recognize in infected spruce since signs and symptoms are seldom produced on live standing trees such as characteristic conks. In recreation sites or other areas where defective trees must be identified, trees need to be bored or drilled to detect decay. In general forest stands this pest is usually not recognized until trees fail or are harvested. Most of these sites readily regenerate naturally back to mixed conifer species that include a component of spruce. Thus, avoiding management of spruce on infected sites is not practical in most cases. Where spruce is to be planted in regeneration units, other species should be used within 50 feet of known infection centers (indicated by decay at the cut surface of spruce stumps). Damage can be minimized by lowering rotation age where this fits management direction. Many riparian stands have a spruce component, and if these stands are managed on an unevenaged system, or restricted to salvage logging only, they will receive the highest levels of tomentosus-caused damage.

Occurrence:

In a study of spruce decay in the Blue Mountains, *I. tomentosus*, was found to be present in 17.1 percent of randomly selected sawlog-size trees (Aho 1971). In casual observations made in a number of stands being salvage logged for windstorm-caused blowdown and spruce beetle-caused mortality, tomentosus root and butt rot has been found wherever there is a a significant spruce component. And in interior British Columbia, spruce as young as 30 years can be severely impacted (Merler et al 1989; Lewis and Hansen 1989).

Effects:

A certain amount of mortality associated with occasional wind break of affected trees is beneficial to stand diversity, especially in riparian areas. However, excessive blowdown would require salvage logging to prevent development of a spruce beetle epidemic. Affected trees in recreation sites may present a hazard potential, and if so, they should be removed.

Western Dwarf Mistletoe

Western dwarf mistletoe (*Arceuthobium campylopodum*) damages ponderosa pine by causing growth loss, some mortality, and varied reductions in wood quality and viability of seed trees.

Hosts and Communities:

The principle host of *A. campylopodum* is ponderosa pine. Lodgepole pine is a secondary host but is seldom infected to a level severe enough to become a management concern.

Ponderosa pine is a stand component in the dry and warm CW series communities, a major component in most of the CD communities, and the dominant component in CP communities. Western dwarf mistletoe can be found on pine growing in most plant communities, but it occurs much less frequently in the CW series than in the dryer CD and CP plant communities. In eastern Washington and Northern Idaho, Daubenmire (1961) found *A. campylopodum* in only the two driest of seven habitat types containing ponderosa pine. Since *A. campylopodum* is quite host specific, it will survive best and spread most readily in stands that have a dominant component of pine. Most communities with a significant component of pine once had a history of light ground fire that kept communities in an early successional stage. Western dwarf mistletoe was thus maintained along with its host on these sites. However, changes in fire history and stand composition in these communities have reduced the pine component in all but some of the CP communities. These are the stands that generally have the highest levels of *A. campylopodum*. While this parasite occurs in all successional stages, it is most common and damaging in early seral multi-age stands with infected overstory trees and susceptible understory trees.

Disease Spread:

Dwarf mistletoes spread by forcibly ejecting sticky seeds from capsules on female plants in the fall. Seeds can be dispersed up to 100 feet, but the distance is usually less than 50 feet from overstory trees and 20-30 feet from smaller trees (Hawksworth and Shaw 1988). Infection results when the seed is intercepted by foliage of its host. Over the winter the seed slides down to the fascicle and germinates in the spring, penetrating the host tissue through the thin bark on fine branches. Initially, a swelling appears, and within 3 to 5 years aerial shoots form that have either staminate or pistillate structures. Spread of infestation through evenaged stands is about 1-2 feet per year (Hawksworth and Shaw 1988).

Stand Conditions:

Spread and resulting damage is highest in pure pine stands, especially those with a multi-layered canopy. Dense, overstocked stands have slower spread rates between trees, but infected trees in such stands tend to be most severely affected. In even-aged stands, efficiency of dwarf mistletoe seed dispersal and effective disease spread is highest with 9-foot tree spacings and is reduced at 18-foot or wider spacing. Impact to infected trees is reduced at wider spacings because individual trees with light to moderate infection levels are able to grow in height faster than mistletoe can spread upward within the crown.

History:

Dwarf mistletoe survey and suppression has been practiced in the Blue Mountain Forests over the last two decades with funds supplied through the Region 6 Forest Pest Management (FPM), program. Suppression work has usually involved cleaning and sanitizing units of infected understory, and destroying infected overstory in closed timber sales that are not planned for reentry for a number of years. However, in most cases, the silvicultural prescriptions for the original suppression projects did not adequately address dwarf mistletoe infestation. Survey work has been instigated to determine dwarf mistletoe occurrence and infestation levels to plan and prioritize treatment needs. Although this work has progressed over the last 20 years, complete records of dwarf mistletoe survey and suppression work in the Blue Mountains are not available.

In the past, spread and damage of western dwarf mistletoe was probably exacerbated by selective harvest techniques that were not followed by sanitation work; thus, infected understory trees were retained. These trees then became sources of infection themselves.

In recent years dwarf mistletoe control has been addressed in most silviculture prescriptions. Control is achieved by integrating dwarf mistletoe management with other vegetative management objectives. As a result, need for post-sale mistletoe control work has been minimized. Most work that is needed can be paid for from K-V funds generated by the project itself. And it is often the case that dwarf mistletoe control is the primary objective of stand treatment.

Management Options:

To reduce dwarf mistletoe impacts, severely infected stands need to be regenerated. However, since natural regeneration is often desired in pine stands, retention of partial cover is frequently required and seed tree and shelterwood systems prescriptions are made which can lead to infection problems. Therefore, infected seed trees should be used as seed sources for natural regeneration only if they are removed before reproduction is 3 feet tall or 10 years old. Stands surrounding regeneration units should be sanitized of infected hosts to minimize spread back into the treatment unit. This can be done by designating a separate individual tree mark (ITM) unit at least 100 feet wide around the perimeter of the regeneration unit.

Stands that are lightly to moderately infected should be converted to a single age class, retaining least-infected trees and spacing the stand to standard stocking levels for managed stands. At managed stocking levels, dwarf mistletoe will have the least possible impact on trees since upper crowns can be kept free of infection. Complete sanitation should be planned as part of a regeneration harvest when infected stands are mature.

Risk Rating:

The Blue Mountain variant of the PROGNOSIS stand simulation model uses Dwarf Mistletoe Ratings (DMR) (Hawksworth 1977) in the tree records to modify growth of infected ponderosa pine. Furthermore, a yield simulator for healthy and dwarf-mistletoe infected stands designed for eastern Oregon is available (Demars and Barrett 1987). The DMR System is a scalar rating from one to six and is based on the amount of infection a tree experiences. This, in turn, can be related to the percentage of growth that would normally be expected for an individual tree. Thus, a rating of "0" means that the tree is growing normally and ratings of one through six signify correspondingly lower values of percentage of growth, which vary depending on whether diameter or height is the growth measurement being discussed.

Occurrence:

Western dwarf mistletoe is extensive in stands on the Baker Ranger District (WAW), Heppner Ranger District (UMA), and all Districts on the Malheur National Forest. Bolsinger (1987) determined that 26 percent of the ponderosa pine type in Washington, Oregon and California is infested with western dwarf mistletoe; occurrence in the Blue Mountains is probably less than this West-wide average. Using the 1968 Wallowa-Whitman Forest Inventory data, Bridgwater (1972) estimated that 6 percent of the ponderosa pine type on the Forest was infested with *A. campylopodum.*

Appendix F-1 includes the mean estimates of occurrence for western dwarf mistletoe by management allocation. Severe levels of infestation occur in wildlife (10% of the area), riparian (10%), old growth (7.5%) and timber and wildlife (8.3%) allocations. Infestation occurs at the low and medium intensities in most allocations.

Effects:

Estimates for height growth reductions for ponderosa pine with DMR 1 through 6 are: 98, 94, 86, 78, and 54 percent of normal growth, respectively. Diameter growth is reduced to: 85, 70, and 50 percent for DMR 4 through 6, respectively (Beatty 1990).

When dwarf mistletoe infection occurs, seed production is reduced. In the southwestern United States, studies have shown that ponderosa pine with DMR's of 3 and greater should not be left for seed. However, ponderosa pine in the Blue Mountains is probably impacted less than similarly infected trees in Arizona.

Furthermore, infected trees are more susceptible to attack and mortality induced by other pests, especially bark beetles (Hawksworth and Shaw 1988). Mortality associated with dwarf mistletoe and beetles or other pests is usually scattered. Such scattered dead trees provide excellent habitat for cavity nesters as well as roosting sites for other species. Low levels of infection thus provide for diversity and can be accepted and desired in most management allocations. Control is needed when infection levels are excessive and management goals are threatened.

Dwarf mistletoe control requires additional costs to evaluate, monitor, and effectively treat affected stands. Silvicultural options are also reduced; potential seed trees cannot be used if they are heavily infected. In some cases of infection, complete sanitation may be needed. Use of fire is usually recommended. Edges adjacent to infected stands need to be minimized to prevent reinfestation if susceptible species are to be regenerated. Stands that are regenerated using an infected overstory need to be revisited after 10-15 years to remove or girdle infected trees. In some cases, a subsequent sanitation thinning may be required.

Of the 16 Ranger Districts surveyed, the number of Districts identifying impact by western dwarf mistletoe for each management allocation is shown in Appendix F-5. Timber and wildlife allocations were identified as being impacted most frequently by western dwarf mistletoe. Appendix F-6 indicates the total area estimated to be impacted by western dwarf mistletoe for each management allocation. The timber and wildlife allocations on the Forests have substantial impacts; 530,000 acres are affected. Lower acreages are believed affected in other allocations.

Douglas-fir Dwarf Mistletoe

Douglas-fir dwarf mistletoe (*Arceuthobium douglasii*) is extremely damaging to Douglas-fir. Infected trees are impacted by growth loss, reduction in wood quality, top-killing, and, in cases of severe infections, mortality.

Hosts and Communities:

The only significant host is Douglas-fir. Several other species of conifers can be slightly affected, but never to a level severe enough to be a management concern.

This dwarf mistletoe is common on its host throughout the range of plant communities that support Douglas-fir. Communities in the Douglas-fir series (CD), such as Psme/Phma and Psme/Syor tend to have relatively high levels of dwarf mistletoe infestation. Douglas-fir in some of the communities of the grand fir series (CW) may also have high levels of infestation. Included in this spectrum are both dry communities such as Abgr/Acgl/Phma, as well as wetter communities like Abgr/Libo. The successional stage in which this pest most commonly occurs seems to be most closely tied with the relative abundance of the host. In the CD series, *A. douglasii* is common in all successional stages, but it tends to be most severe in later seral and climax vegetation. In the CW series *A. douglasii* is most common in early to mid seral vegetation. Mortality is most severe on poor sites, such as ridgetops with shallow soils.

Disease Spread:

Dwarf mistletoes spread by forcibly ejecting sticky seeds from capsules on female plants in the fall. Most seeds are dispersed less than 10 feet. Infection results when the seed is intercepted by foliage of its host. Over the winter, the seed slides down to the host's fascicle and germinates in the spring, penetrating the host tissue through the thin bark of fine branches. Unlike other dwarf mistletoes, branch swelling is not characteristically associated with *A. douglasii* infection and formation of aerial shoots. Plants are small, usually about needle-length, dioecious, and approximately equal numbers of male and female plants occur on a given host.

Stand Conditions:

Spread and damage is highest in stands dominated by Douglas-fir. In many communities, Douglas-fir, a shade tolerant species, is a major component of developing understory under a closed canopy. Such a stand condition is most conducive for dwarf mistletoe spread and intensification. Infections remain dormant or underdeveloped in shaded conditions, but soon after stand is opened, dwarf mistletoe plants respond, resulting in shoot formation, intensification of infections on individual trees, and host brooming. When released, infected trees in the understory will usually be become severely broomed within 15 to 20 years; at that point, growth all but stops and mortality can occur. Knudson and Tinnin (1985) report that in even-aged, thinned stands of fir growth response occurs in lightly and moderately infected trees. However, infection levels, increased (DMR) and long-term effects on infection have yet to be determined.

History:

Dwarf mistletoe survey and suppression has been practiced in the Blue Mountain Forests over the last two decades with funds supplied through the Region 6 Forest Pest Management (FPM). Suppression work has usually involved cleaning and sanitizing units of infected understory, and destroying infected overstory in closed timber sales that are not planned for reentry for a number of years. However, in most cases, the silvicultural prescriptions for the original projects did not adequately address dwarf mistletoe infestation. Survey work has been initiated to determine dwarf mistletoe occurrence and infestation levels to plan and prioritize treatment needs. Although this work has progressed over the last 20 years, complete records of dwarf mistletoe survey and suppression work in the Blue Mountains are not available.

Most direct suppression work has involved sanitizing residual Douglas-fir stands of infected trees following partial removal harvests. However, it is often the case that small diameter and unmerchantable dwarf mistletoe-infected Douglas-fir residuals are left untreated in harvest units.

Incidence of, and damage by *A. douglasii* has probably increased over the last few decades. This is due to the fact that fire exclusion has resulted in development of susceptible Douglas-fir understory in many CP, CD, and dry CW communities and infected overstory trees have often been left in partial-cut entries.

In recent years dwarf mistletoe control has been addressed in most silvicultural prescriptions. Control is achieved by integrating dwarf mistletoe management with other vegetative management objectives. As a result, need for post-sale mistletoe control work has been minimized, and most of the work that is needed can be paid for from KV funds generated by the project. Oftentimes, dwarf mistletoe control is the primary objective of stand treatment. Recently, sanitizing stands of unmerchantable dwarf mistletoe-infected Douglas-fir has been achieved by offering this material in commercial fuelwood sales on the Pomeroy Ranger District (UMA). Also, the Prairie City Ranger District (MAL) revised their stand improvement (precommercial thinning) specifications to designate preferred species and allow removal of dwarf mistletoe-infected trees, thus retaining healthier, although smaller diameter, trees.

Management Options:

To reduce impacts, regenerate severely infected stands and favor non-hosts in mixed stands. Use fire to sanitize understories. Carefully evaluate stands that have an infected overstory and a susceptible understory before attempting to sanitize and manage residual stocking of Douglas-fir. Note that Douglas-fir understory growing within 20 feet of infected overstory trees are probably infected even if mistletoe plants and brooms are not apparent. Such trees should not be managed for timber unless their diameters are within 1 inch of merchantability standards. Stands with few or localized infected overstory trees may have viable understory, and that should be taken into account in the management prescription. Stands surrounding regeneration units should be sanitized of infected hosts to minimize spread back into treatment units. This can be done by designating a separate individual tree mark (ITM) unit at least 1-chain (66 feet) wide around the perimeter of the regeneration unit.

Douglas-firs with dwarf mistletoe brooms are sometimes used by certain wildlife species for nesting sites and hiding cover (Bull and Henjum 1990). So some should be kept in stands or portions of stands where infected trees are to be managed for wildlife, but an effort should be made to limit spread into surrounding stands. Physical barriers (streams, ridges, etc.) or managed barriers of non-host trees can be used to isolate pockets of infected trees.

Risk Rating:

Impact of Douglas-fir dwarf mistletoe is simulated in the PROGNOSIS model. Dwarf mistletoe infestation is read from the damage codes in the individual tree records. Work is currently being done on updating the growth impact and mortality functions of Douglas-fir dwarf mistletoe in the model. The updated version is expected to be in place early in 1991.

Occurrence:

East Side Douglas-fir stands in Region six have a 42 percent rate of infestation by Douglas-fir dwarf mistletoe (Bolinger 1978). Using the 1968 Wallowa-Whitman Forest Inventory data, Bridgwater (1972) estimated that 11 percent of the Douglas-fir type on the Forest was infested with *A. douglasii*. A later survey on the Wallowa-Whitman NF indicated that 13.4 and 18.7 percent of the Douglas-fir stems were infected with *A. douglasii* on CD/CP, and CW sites, respectively (Schmitt et al 1991). These rates of infection are believed to be similar throughout the forested land in the Blue Mountains.

Appendix F-1 includes the mean estimates of occurrence of Douglas-fir dwarf mistletoe by management allocation. Low and medium levels of infestation are common in all allocations. High severity was identified in 80% of areas in viewshed allocations, 40% of areas in wilderness allocations, and 19% of areas in wildlife allocations. Severe levels of infestation occur in timber and wildlife (5.1%), old growth (8%), wildlife (6.25%), riparian (7%), and wilderness (5%).

In Appendix F-3, Douglas-fir dwarf mistletoe was identified in the Douglas-fir, grand fir, and subalpine fir series. Most occurs in the Douglas-fir series (57.7% of series is infested); low, medium, and high intensities predominate. Significant occurrence also exists at low intensities in the grand fir series.

Effects:

Dwarf mistletoe-infected Douglas-fir are predisposed to mortality, especially after becoming heavily infected. This makes snags available for roosting and, in some cases, use by cavity nesters. In addition, live-infected trees often have large brooms that are used as cover by owls and grouse, and infected trees along ridge tops are most frequently used by such birds. Thus, where dwarf mistletoe is localized and does not threaten long-term goals of affected management allocations, occasional mortality and associated broomed live-infected trees, are desirable.

Where timber resources are a management goal, Douglas-fir dwarf mistletoe needs to be controlled. Affected stands are often difficult to efficiently manage, and associated costs run higher than they do corresponding healthy stands. Understories of such stands are usually not manageable, thus, survey, sanitation, and regeneration costs are incurred.

Estimates for height growth impacts for trees with DMR 1 through 6 are reductions to: 98, 94, 86, 70, 38, and 6 percent of normal growth, respectively. Similar diameter growth reductions are: 90, 90, 60, 60, 30, and 30 percent of the norm. Estimates for mortality of sawlog-size trees for 1-year periods for DMR 3 through 6 are: 1, 4, 10, and 10 percent of stems (Beatty 1990). In reviewing inventory plots for the effects of interaction between the western spruce budworm and douglas-fir dwarf mistletoe, Filip et al (1990b) found ten year mortality of moderately infected trees averaged 2 percent of the basal area. Mortality of severely infected trees was 3 percent of the basal area over a ten-year period.

Of the 16 Ranger Districts surveyed, the number of Districts identifying impact by Douglas-fir dwarf mistletoe for each management allocation is shown in Appendix F-5. Timber and wildlife allocations were identified as being impacted most frequently by Douglas-fir dwarf mistletoe. Appendix F-6 indicates the total area estimated to be impacted by Douglas-fir dwarf mistletoe for each management allocation. Most allocations are affected; timber and wildlife allocations have about 230,000 acres infected.

The following example (Fig. II-28) of the effects of Douglas-fir and western larch dwarf mistletoes is based on 100-year PROGNOSIS model simulations of two data sets (all trees uninfected and some trees infected) combined with actual stand data. The uninfected simulation portrays growth of the existing stand with the effects of dwarf mistletoes removed. The infected simulation portrays growth of the same existing stand with both Douglas-fir and western larch dwarf mistletoes infection parameters. All other tree, stand, and stocking data at the beginning of the stimulations are identical for each simulation.

Current existing parameters:

Stand 0003; Compartment 6001; La Grande RD (WAW)

Species composition by stems

Douglas-fir	41%
grand fir	42%
Engelmann spruce	6%
western larch	12%

Trees per acre-	232
Basal area-	231
Crown Competition Factor-	184
Plant Community-	CW-S2-11
Elevation-	5,200 ft.

Dwarf mistletoe data in infected simulation
(current and projected values):

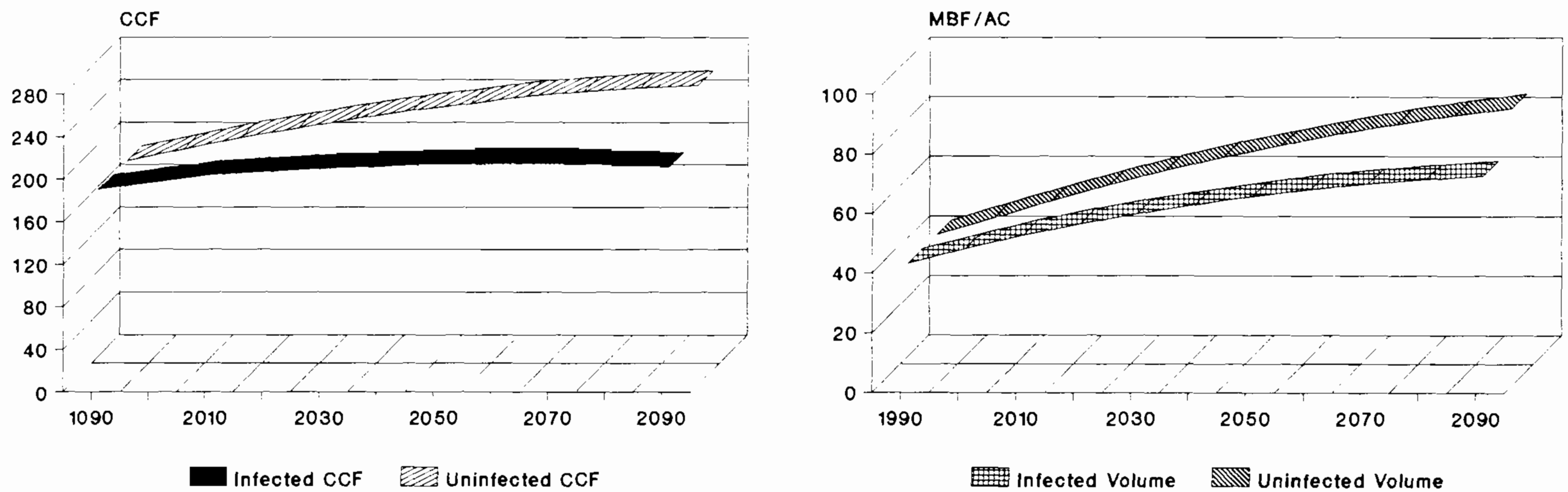
Mean Dwarf Mistletoe Rating (DMR)

1990	Douglas-fir=	3.3
	western larch=	3.0
2090	Douglas-fir=	4.3
	western larch=	5.2

Percent infection (stems)

1990	Douglas-fir=	67%
	western larch=	86%
2090	Douglas fir=	83%
	western larch=	96%

PROGNOSIS Growth Simulation With Dwarf Mistletoe Extension Modeling Effects of Douglas-fir and Western Larch Dwarf Mistletoes



Stand 0003
Compartment 6001
LaGrande Ranger District (WAW)

Figure II-28

Lodgepole Pine Dwarf Mistletoe

Lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) damages its hosts by causing growth loss, mortality, reduction in wood quality, and alterations in stand development.

Hosts and Communities:

The principle host is lodgepole pine, although western larch is sometimes damaged by *A. americanum*. Larch infestation usually occurs in communities where larch understory develops under a mature to overmature overstory of lodgepole pine.

Lodgepole pine dwarf mistletoe usually develops in centers around scattered survivors of stand replacement fires. As stands mature, dwarf mistletoe spreads and intensifies, but the highest levels of infection center around locations of old survivors, even when these are no longer present.

Lodgepole pine dwarf mistletoe is most severe in stands dominated by lodgepole in early through late seral stages of succession. This includes communities in the CL series and some CE and CW communities. Dwarf mistletoe can occur in mixed conifer stands but usually occurrence and severity of dwarf mistletoe in such stands are lower. Western larch may be damaged where it is seral along with lodgepole pine in communities such as the subalpine fir, grand fir/big huckleberry and grand fir/grouse huckleberry community groups.

In the Rocky Mountains, several separate studies indicate that subalpine fir/grouse huckleberry and lodgepole pine/bearberry communities had high levels of dwarf mistletoe in lodgepole pine (Roe and Amman 1970; Mauk and Henderson 1984). These communities are similar to classifications made for the Blue Mountains and Wallowa-Snake Province (Johnson and Simon 1987; Johnson and Hall 1990)

Disease Spread:

Dwarf mistletoes spread by forcibly ejecting sticky seeds from capsules on female plants in the fall. Average seed dispersal ranges from 22 to 45 feet (Hawksworth and Johnson 1989). Infection results when the seed is intercepted by foliage of its host. Over the winter the seed slides down to the hosts' fascicle and germinates in the spring, penetrating the host tissue through the thin bark on fine branches. Initially, a swelling appears, and within 3 to 5 years either staminate or pistillate aerial shoots form.

Spread through young lodgepole pine is 1.5 times greater in open-canopied stands than in stands with closed canopies. This is illustrated by the fact that spread has been observed at 1.7 feet and 1.2 feet per year in evenaged open and dense stands, respectively (Hawksworth and Johnson 1989).

Stand Conditions:

Hadfield (1977) found no direct relationship between site quality and dwarf mistletoe frequency in eastern Oregon; dwarf mistletoe was most frequent in sites 65 to 75 feet, and least in stands over site 85 (height at base age 100). Lodgepole pine usually occurs as an early seral species in mixed conifer stands and in largely single age class pure stands. And where lodgepole pine dominates a stand, mistletoe spread and damage tend to be most severe.

Patterns of fire influence the occurrence of dwarf mistletoe. Baranyay (1972) found that dissimilarities in fire history between different areas dictated the intensity and distribution of dwarf mistletoe. For example, stands that have large extensive wildfires experience much lower levels of dwarf mistletoe infection than do stands with variable topography and conditions that allowed survival of patches of timber, and thus perpetuating infection.

Partial cutting in stands may intensify the occurrence of dwarf mistletoe. (Lotan and Perry 1983). Hawksworth and Johnson (1989) report that the percentage of stands infested with dwarf mistletoe is lowest in regenerated burns, and highest in partially cut stands.

Management Options: Management direction for infested stands is determined by management objectives and desired resource outputs. To reduce losses caused by dwarf mistletoes consider the following:

> *Overmature stands-* Regeneration harvests are recommended for overmature stands of lodgepole regardless of infestation intensity. Natural regeneration should be preferred where adequate numbers of healthy or lightly infected trees occur. Remove infected seed trees before regeneration is 3 feet tall or 10 years old. If the stand is severely infected, consider artificial regeneration.
>
> *Mature stands-* Survey the stand to determine severity and extent of infection. If the stand is lightly infested (full stocking of healthy and lightly infected trees exists) consider a sanitation commercial thinning. If the stand has a high level of infection, regenerate using any available seed trees.
>
> *Precommercial stands-* Survey the stand to determine severity and extent of infection. If the stand is lightly infested, consider a sanitation thinning. If the stand is heavily infested, consider complete replacement.

On any site where an infested stand is being replaced the following are recommended:

> -Use topography and human-made features to minimize edges between adjacent infested stands and the regenerated unit.
>
> -Remove or destroy all infected trees before an area is planted or regenerated with susceptible hosts.
>
> -Use non-hosts as much as possible where dwarf mistletoe is a hazard.

Risk Rating:

The Blue Mountain variant of the PROGNOSIS stand simulation model uses dwarf mistletoe ratings in the tree records to modify growth of infected trees. The current version of the model is believed to accurately simulate the effect of lodgepole pine dwarf mistletoe. Several other models have been developed to simulate yield impacts on affected trees, including a model that provides an economic analysis for scheduling harvesting of managed stands (Schmitt and Wiitala 1983). Due to the considerable range in site and stand characteristics (and related dwarf mistletoe effects) on the Forests, these models should be applied only to localities for which they are built.

Occurrence:

Lodgepole pine dwarf mistletoe is widely scattered throughout the three Forests, but it is present to some degree in most expanses of lodgepole pine. Using the 1968 Wallowa-Whitman Forest Inventory data, Bridgwater (1972) estimated that 4 percent of the lodgepole pine type on the Forest was infested with *A. americanum* and *A. laricis*. Bolsinger (1978), using Forest Inventory data, estimated that 42 percent of the lodgepole pine in the Northwest and northern California is infested with dwarf mistletoe.

Appendix F-1 includes the mean estimates of occurrence of lodgepole pine dwarf mistletoe by management allocation. Highest occurrence in the severe and high intensities are in the riparian (17.5%, 32.5%) and wilderness allocations (10%, 20%), respectively. Low and medium intensities occur in most other allocations, being most common in viewshed (54.5%, 10%) and timber and wildlife allocations (7.5%, 26.0%). Plant association series identified as being infected include the subalpine fir and grand fir series. The subalpine fir series had the highest identified occurrence (Appendix F-3).

Effects:

Seed and cone production are impacted by dwarf mistletoe. Schaffer et al (1983) found that in heavily infected trees, smaller cones, fewer cones, fewer filled seeds, lower germination of filled seeds, and smaller seed size were all caused by dwarf mistletoe infestation.

Estimates for height growth impacts for trees with DMR 2 through 6 are reductions to: 98, 94, 86, 78, and 70 percent of normal growth, respectively. Similar diameter growth reduction for DMR 4 through DMR 6 are: 94, 80, and 59 percent of the norm. Estimates for mortality of sawlog-size trees for 1-year periods for DMR 1 through 6 are: 3, 3, 6, 6, 7, and 7 percent of stems (Parks 1990).

Little published information is available on the effects of lodgepole pine dwarf mistletoe on other resource values. Wildlife, especially birds, use brooms for hiding and nesting sites, and snag-dependent species use killed trees.

In the presence of the dwarf mistletoe, extra costs associated with survey, sanitation, and regenerating affected sites are incurred. Therefore, costs and other required resources for stand treatment are higher for infested stands than they are for correspondingly healthy stands.

Of the 16 Ranger Districts surveyed, the number of Districts identifying impact by lodgepole pine dwarf mistletoe for each management allocation is shown in Appendix F-5. Timber and wildlife allocations were identified as being impacted most frequently by lodgepole pine dwarf mistletoe. Appendix F-6 indicates the total area estimated to be impacted by lodgepole pine dwarf mistletoe for each management allocation. Timber and wildlife, and wilderness allocations have most infections, 53,000 and 40,000 acres, respectively. Very low acreage is believed affected in other allocations.

Larch Dwarf Mistletoe

Larch dwarf mistletoe (*Arceuthobium laricis*) damages western larch by causing crowns to deteriorate, and as the infection progresses, branches broom and eventually break off. Infected trees have reduced growth, provide less seed, and usually die when infection becomes severe.

Hosts and Communities:

Western larch is the only significant host of this dwarf mistletoe, and all plant communities containing a component of larch are damaged by it. Sources of infestation are usually scattered trees that survive stand replacement fires. Spread is greatest in early successional stages, and most impacts occur in stands of sawlog-size trees at mid seral stages when larch are mature.

Disease Spread:

Dwarf mistletoes spread by forcibly ejecting sticky seeds from capsules on female plants in the fall. Seeds can be dispersed up to 45 feet (Smith 1966). Infection results when the seeds are intercepted by host-foliage. Seeds slide down to the spur of the host tree where they overwinter and germinate in the spring. Shortly after infection a swelling appears, and within 3 to 5 years either staminate or pistillate (male or female) shoots form.

Stand Conditions:

Larch dwarf mistletoe infects a higher proportion of its host than any other dwarf mistletoe. This is surprising since larch usually grows in a mixed conifer situation, interspersed with non-hosts.

History:

Dwarf mistletoe suppression and survey have been practiced in the Blue Mountain Forests over the last two decades with funds supplied through the Region 6 Forest Pest Management (FPM) program. Suppression work has usually involved cleaning and sanitizing units of infected understory, and removing infected overstory in closed timber sales that are not planned for reentry for a number of years. In most cases the silvicultural prescriptions for the original suppression projects did not adequately address dwarf mistletoe infestation. Survey work has also been done; its purpose being the determination of dwarf mistletoe occurrence and infestation levels, and the planning and prioritizing of treatment needs. However, complete records of dwarf mistletoe survey and suppression work in the Blue Mountains are not available.

In recent years dwarf mistletoe control has been addressed in most silvicultural prescriptions. Suppression has been achieved by integrating dwarf mistletoe management with other vegetative management objectives. As a result, need for post-sale mistletoe control work has been minimized, and most of the work that is needed can be paid for from KV funds generated by the project. Oftentimes, dwarf mistletoe suppression is the primary objective of stand treatment.

Management Options:

Severely infested stands should be regenerated, and those with viable developing understory overtopped by dwarf mistletoe-infected overstory should be given highest priority in all modes of treatment. Immature 9 to 15 inch dbh larch stands should be thinned to 90 ft.^{2}/acre to increase growth and vigor of healthy and lightly infected trees (DMR = 0-2). If adequate stocking can be maintained, and stands will not be entered for over 20 years, moderately infected trees (DMR = 3-4) should also be removed since moderate infections tend to intensify. Severely infected trees (DMR = 5-6) will not respond to thinning and are prime sources of infection for developing larch understory (Filip et al 1989). To successfully use natural regeneration silviculture systems, regenerate infested stands while at least 10 to 12 larch trees remain that are viable seed producers with adequate crowns. Once regeneration is accomplished, remove these seed trees before the developing regeneration is 3 feet tall or 10 years old.

Risk Rating:

Larch dwarf mistletoe infestation impacts are simulated in the PROGNOSIS model. Dwarf mistletoe ratings (DMR) are read from the damage codes for trees in the tree records. The impact equations in the model have recently been updated to more accurately simulate the effects of larch dwarf mistletoe.

Occurrence:

Larch dwarf mistletoe infects 47 percent of the larch type in Washington and Oregon (Bolsinger 1978). Using the 1968 Wallowa-Whitman Forest Inventory data, Bridgwater (1972) estimated that 18 percent of the larch type on the Forest was infested with *A. laricis*. On the Wallowa-Whitman National Forest, Schmitt et al (1991) found 38 percent and 51 percent of larch stems infected in unentered wet CW and dry CW communities, respectively (Schmitt et al 1991). These infection rates are believed to be similar for larch throughout the Blue Mountains.

Appendix F-1 includes the mean estimates of occurrence of larch dwarf mistletoe by management allocation. Severe and high intensities of larch dwarf mistletoe were identified in most allocations; highest were in the old growth and wilderness allocations; both had 10% of area infested at severe and high intensities. Extensive areas of infection were identified at low and moderate levels of infestation; viewshed (52.0%, 15%), wildlife (38.0%, 16.3%), wilderness (26.5%, 9%), and timber and wildlife (21.8%, 23%), respectively. Infestation was highest in the grand fir association series, especially in the low and medium intensities (Appendix F-3).

Effects:

Costs associated with survey, sanitation, and regenerating affected sites are incurred. Thus, costs and other required resource expenditures for stand treatment are higher for infested stands than in correspondingly healthy stands. One reason is that larch is a poor seed producer when moderately or severely affected with dwarf mistletoe.

Mortality of severely infected trees is common. Such snags are preferred by cavity nesters, but snags near roads are difficult to retain because of the popularity of larch snags for fuelwood.

Estimates of impact on infected trees have been quantified in terms of reduction in height and diameter growth and increased mortality. Height growth impacts for trees with DMR 1 through 6 are reductions to: 98, 94, 86, 70, 38, and 6 percent normal growth, respectively. Similar diameter growth impacts are reductions in normal growth to: 97, 90, 85, 69, 57, and 44 percent, respectively. Mortality estimates for 1-year periods for DMR 3 through 6 are: 1, 2, 7, and 13 percent of stems (Beatty 1990).

Of the 16 Ranger Districts surveyed, the number of Districts identifying impact by larch dwarf mistletoe for each management allocation is shown in Appendix F-5. Timber and wildlife allocations were identified as being impacted most frequently by larch dwarf mistletoe. Appendix F-6 indicates the total area estimated to be impacted by larch dwarf mistletoe each management allocation. Timber and wildlife allocations have substantial amounts of infection; 118,000 acres are impacted. Low acreage is believed affected in most other allocations.

Rust Red Stringy Rot

Indian paint fungus (*Echinodontium tinctorium*) causes extensive stem decay of true firs. One conk indicates up to 40 feet of cull. Often, trees have multiple conks or a single conk with other indicators such as wounds or frost cracks. Such trees are completely defective for use as commercial sawlogs. However, the trees may be used as pulp or fuel when market conditions are favorable. This disease is extremely damaging in many grand/white fir stands.

Hosts and Communities:

Grand fir and white fir are the principle hosts of this disease. Although subalpine fir can also be affected. Damage can be extensive, especially in old stands on wet sites. Filip et al (1983) found that fir in communities currently or previously dominated by ponderosa pine had less decay and infection than fir growing on sites historically dominated by overstory firs. While formal Plant Community data was not reported, this observation would tend to indicate that the highest disease levels occur in wet CW communities and lower levels occur in stands dominated by pines in the early successional stages (dry CW, CD, CP). Schmitt et al (1991) found the highest incidences of Indian paint fungus decay to occur in grand fir in Abgr/Tabr/Clun (24.4% of fir basal area), Abgr/Vasc (14.4%), and Abgr/Libo (8.6%) communities.

Disease Spread:

E. tinctorium spreads via airborne spores which are released from fruiting bodies (conks). Spores infect susceptible hosts through branch traces (small stubs exposed when branchlets fall off), and the infections become encased in the bole as trees increase in diameter. Long-suppressed understory trees have much greater opportunities to become infected than vigorous, open grown firs. Infections are often multiple and remain dormant for many years. Infections are activated by mechanical injuries, frost cracks, killed tops, and fir engraver (*Scolytus ventralis*) attacks. Generally, the larger the wound the more rapid and extensive decay.

After decay has become well developed, conks may be produced. Conks are usually found near the center of the decay column and almost always fruit at a branch or branch stub.

Stand Conditions:

Stands managed on an unevenaged system in grand fir communities (especially moist Abgr communities) tend to have the highest rates of infection and resulting decay. Such stands develop as a result of partial cutting, especially in selection (ITM) and overstory removal (OR) prescriptions. In such situations, grand fir is favored to regenerate under a closed canopy. Understory grand fir grow slowly and will not release until the overstory trees around them are removed or die. Exclusion of light ground fire has favored the development and survival of this understory component. But when released understory trees eventually become dominant, because of the many years of suppression they undergo, they tend to have multiple *E. tinctorium* infections. Amount of decay is also closely related to tree age: Trees over 150 years old tend to have substantially more decay than trees in younger stands.

Injuries and disturbances may activate infections which result in decay, and partially-cut stands all have some level of wounding as the result of falling and skidding damage to residuals. Furthermore, stands dominated by firs often have some defoliator-caused damage. In stands having had severe defoliation, killed tops can result in activation of decay. Other decay fungi are also common in stands of white and grand fir: *Heterobasidion annosum, Pholiota limonella, Hericium abietis*, and *Sterium sanguinolentum* are some examples (Aho et al 1987).

History:

Damage caused by Indian paint fungus is often excessive in old stands of grand and white fir. Damage is expected to be severe in developing stands of white and grand fir that are suppressed for many years, released in overstory removal harvests, and designated as future crop trees. Management direction to manage advanced true fir regeneration was common on Blue Mountain National Forest's until recent years. The most frequently cited reason for this direction is that costs associated with site preparation and reforestation were avoided, usually in timber sales that would have been deficit if this work were to be done. But it is important to understand that the hazard to advanced grand and white fir regeneration was not realized until recently, so past managers had no way of knowing that this particular long-term effect would occur.

Management Options:

Manage seral species on CD, CP, and dry CW sites. True firs should be managed on wet CW sites as a component with other associated species. Maintain stand vigor; fir stands should be managed for less than 150 years, as stands older than that can have excessive decay. Avoid stand conditions that favor *E. tinctorium* infection; establish firs under a shelterwood or seed tree system to avoid suppression. Do not manage firs that have been suppressed for over 50 years.

While they're sapling- to pole-sized, space stands in a manner that avoids the need for commercial thinning entries. Consider favoring pines, larch, and Douglas-fir regeneration. If commercial entries are made, avoid wounding residuals or remove firs that are wounded.

Risk Rating:

Stand simulation models do not consider the effects of Indian paint fungus. Pathologists and silviculturists believe that future yield projections of PROGNOSIS model simulations in stands with *E. tinctorium* -infected understory are not realistic. However, Filip et al (1983) describes a understory risk rating system that can help to assess viability of grand fir understory.

Occurrence:

Indian paint fungus is extremely common, and some level of infection occurs in most grand and white fir stands. Infection tends to be a characteristic of the stand history and community type: true firs on wet CW communities that have been suppressed for at least 50 years occur on all Forests in the Blue Mountains, and excessive levels of decay can be expected when these conditions exist.

Stands recently surveyed on the Wallowa-Whitman NF indicate current Indian paint-caused defect is present in 4.4 and 9.0 percent of the total grand fir basal area for trees in CP/CD, and CW sites, respectively. These figures are believed to be representative of grand fir and white fir throughout the Blue Mountains (Schmitt et al 1991).

Appendix F includes the mean estimates of occurrence of Indian paint fungus by management allocation. Severe intensities of Indian paint fungus occur in most allocations: viewshed (30% of area), timber and wildlife (19.7%, wildlife (30%), riparian, and old growth (both 16.7%). The grand fir series has the highest occurrence of Indian paint fungus. Other affected allocations include subalpine fir and mountain hemlock (Appendix F-3).

Effects:

Indian paint fungus-caused decay affects timber-related values both by causing defect in existing timber, and by creating non viable stands of existing infected understory. In addition, Aho (1977) found that decay (most commonly caused by E. tinctorium, but including other sources) resulted in a 40 percent board foot volume defect in Blue Mountains stands. However, old stands with extensive decay may retain most non-timber related values. For example, occasional trees will fail, tending to add large downed material to the forest floor, and cavity nesting birds will use decayed trees.

When stands with high levels of decay are harvested, large amounts of slash and residue accumulation may need to be disposed of. Furthermore, stands with high levels of defect affect timber resource productivity by postponing site recovery and management of healthy stands.

Of the 16 Ranger Districts surveyed, the number of Districts identifying impact by Indian paint fungus for each management allocation is shown in Appendix F-5. Timber and wildlife allocations were identified as being impacted most frequently by Indian paint fungus. Appendix F-6 indicates the total area estimated to be impacted by Indian paint fungus for each management allocation. Most allocations have an impact. Most substantial are timber and wildlife allocations; 640,000 acres affected. Wilderness and wildlife allocations are also significantly infected: 82,000 and 52,000 acres, respectively.

Western Gall Rust

Western gall rust is caused by the fungus, *Endocronartium* (*Peridermium*) *harknessii*. This fungus is native to north America. *E. harknessii* causes a stem and branch canker on two and three needle pines. Infected trees may be affected by stem deformation, breakage, and mortality.

Hosts and Communities:

Lodgepole pine is highly susceptible to this disease and most stands are infected. Ponderosa pine can also be infected, but susceptibility of ponderosa pine varies considerably among individuals and with geographic origin of seed. Hadfield (1977) found that lodgepole pine communities with shrub vegetation, as opposed to meadow or grass vegetation, had highest incidence of gall rust. He also found no differences in disease levels on different quality sites, although it is generally believed that trees on higher quality sites are more susceptible to infection. Damage can be most severe in stands dominated by lodgepole pine. These include stands in the CL series and some CE and CW communities, especially in early successional stages.

Disease Spread:

E. harknessii spreads via airborne spores. Peterson (1971) reports that most stand infections originated in 1 or 2 years in a 10-year sample period. Epidemics are usually only a few miles in extent, but occasional wave years may occur over vast areas. Aecia are produced in the spring and early summer on cankers of live hosts; they then release spores which infect other host pines. No alternate host is needed as in most other rusts, however there is evidence that some strains of *E. harknessii* may alternate on paintbrush (*Castilleja* sp.). Moist conditions stimulate spore release and favor infection. Infection occurs on succulent stem and branch tissue.

Stand Conditions:

Infection is most damaging in young stands since seedlings and saplings are more likely to develop lethal bole infections. High hazard sites are more prone to frequent and excessive infection, and subsequent damage. For example, spaced stands tend to have higher rates of infestation since faster growing trees are most susceptible to infection.

Management Options:

There is genetic variation in susceptibility to western gall rust between individual lodgepole pines. During any stand improvement activity, trees exhibiting resistance should be favored for retention. Branch galls are less serious than stem galls. Large galls that are deeply indented on sawlog-size trees can predispose hosts to failure. Such trees should be removed from recreation sites if they are deemed hazardous.

Occurrence:

This native rust occurs throughout most stands of lodgepole pine. Considerable variation occurs in incidence. Most severely-infected stands are believed on high-hazard sites.

Effects:

Western gall rust-affected pines are frequently considered a hazard in recreation sites. Galls or "hip-cankers" on the main stem of trees can kill the top or weaken the tree at the site of the canker, rendering it susceptible to failure.

Frequently, galls on young trees will result in mortality. Since many stands of lodgepole are severely overstocked, this can be considered a benefit, as western gall rust-induced mortality will act to naturally thin such a stand.

Elytroderma Needle Blight

Elytroderma needle blight is caused by the fungus, *Elytroderma deformans*. This is the most damaging foliage disease to infect ponderosa pine. Elytroderma blight results in premature death of 1-year old needles. Occurrence of Elytroderma needle blight is concentrated around a 5000' elevation band (Childs 1968). Severely infected trees are impacted by growth loss, deformation, attack by bark beetles, and infrequently, outright mortality.

Hosts and Communities:

Ponderosa pine is a common host and lodgepole pine is an occasional host. The highest levels of occurrence (and corresponding management concern) are found in ponderosa pine. Childs (1968) reported that infection of ponderosa pine less than 30 years old is uncommon, however observations made in recent years in a variety of Blue Mountain sites do not support this. In fact, observations show that all size classes can be infected and resulting damage is most severe to saplings and poles. Although infection is usually highest in the lower crown of larger trees.

Communities dominated by ponderosa pine (both as overstory and understory components), are most severely affected. Such sites can be found on the dry end of the mixed conifer series (CW), but more commonly Elytroderma is found on CD and wet CP sites.

Disease Spread:

Spores are released from fruiting bodies on needles in mid to late summer, but spread is a relatively rare event since cool temperatures and high humidity are required for extended periods of time. In fact, microsites where these conditions most likely exist usually coincide with the highest disease incidence, and the existence of such sites can sometimes lead to local epidemics.

During infestation, only current year needles are infected. Once needles become infected, the fungus grows from needles into the twigs. *E. deformans* grows in the inner bark of twigs and branches of its hosts. The fungus thus becomes systemic and will re-infect new growth in subsequent years on infected branches. However, there is little effect on the host until more than 40 percent of the twigs are blighted (Bega 1978), and infections may die when infected lower branches are shaded and die.

Stand Conditions:

Ponderosa pine growing on most wet, cool micro sites is most susceptible to infection. Such sites are found along draws, in lower slope positions, and adjacent to large openings such as meadows or scabs.

Management Options:

Although it is unproven, there is probably some level of genetic variability in susceptibility to Elytroderma blight. Sinclair et al (1987) reports that occasional uninfected trees exist in areas of severe infection. Trees exhibiting resistance to infection should be favored for retention in stand entries.

In Immature Stands:

(1) Infected or high hazard stands should have adequate spacing, but avoid creating large openings,

(2) In thinnings, remove those most severely infected individuals. Young trees with terminals infected should not be retained.

In Mature Stands:

(1) Recognize that considerable infection can occur without causing appreciable damage; avoid taking hasty action:

(2) Monitor conditions annually where infection is high. If mortality begins to occur, consider action,

(3) Treat stands when damage becomes excessive. Reduce stocking by removing most severely infected trees.

Occurrence:

Several areas in the Blue Mountains have levels of Elytroderma that are severe. Among these include stands on the North Fork John Day Ranger District (UMA), Baker Ranger District (WAW), and Long Creek Ranger District (MAL). The extensive ponderosa pine stands on the southern portion of the Malheur National Forest have relatively light infestations.

Effects:

It has been noted that young to mature pine with 30 to 60 percent of the twigs flagged by Elytroderma had diameter growth reduced to 35 to 48 percent of normal. Pine with greater than 60 percent branch flagging had growth reduced to 1 to 7 percent of normal (Childs 1968). Seedlings and saplings that become infected may become permanently stunted and deformed. Sawlog-size trees may be predisposed to other pests, especially bark beetles.

Needle Diseases of Larch

Two foliage diseases are common on western larch: Larch needle blight, caused by the fungus *Hypodermella laricis*, and needle cast of larch, caused by the fungus, *Meria laricis*. These needle casts are common over wide areas, especially in years having cool and moist spring weather when new needles are emerging. These diseases often appear spectacular, causing foliage on hosts to prematurely discolor and die. However, concern is largely unwarranted in forest stands, because damage is generally minor, and restricted to a low level of growth loss on most affected trees.

Hosts and Communities:

Western larch and subalpine larch are hosts to these needle diseases. Western larch is most susceptible on sites that are apt to have cool and moist conditions. Draws, streamsides, lower slope locations, etc., are where needle blights are most likely to be found. Western larch is found in CW, CE, and CD series communities; occurrence of needle diseases is most common in the wet CW and CE communities.

Disease Spread:

Larch needle diseases are spread by airborne spores produced from old infected needles in the duff; between trees; and in some cases, by rain splash from old infected foliage to healthy foliage on individual trees. Spread begins in the spring as soon as needles emerge. *M. laricis* will continue to infect larch needles as long as wet weather continues.

Stand Conditions:

High hazard sites will frequently be affected by needle blights.

Management Options:

Generally, management action is not warranted in forest stands, but fungicides are available for use in specific situations where protection is needed. This may be considered appropriate in progeny test plantations, seed orchards, nurseries, etc.

Effects:

Damage is usually low in terms of growth loss. Impacts to other resources may be significant. Visual quality may be substantially impacted in years that have high levels of infection.

Occurrence:

During years favorable for these diseases, needle blights can occur throughout the host type. Most infection will be concentrated in sites conducive for infection, as described above.

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INSECTS AND DISEASES AND HOW THEY RELATE TO ISSUES

Issue 1 - **Planning**

Forest Plans for the Blue Mountains National Forests establish many Standards and Guidelines that relate to the managing of forest insects and diseases. The Standards and Guidelines give specific management direction for the handling of pest-related problems in both the contexts of timber and non-timber resources. However, that management direction, while fully capable of addressing Desired Future Condition as it relates to potential insect and disease problems on a healthy forest, may not be appropriate on forested lands already experiencing an accelerating deterioration in health. Furthermore, even when the presently accepted management is adequate, it is often given a priority low enough that implementation of the direction becomes difficult.

Given current infestation levels, Forest Plans lack sufficient pest impact information, although the degree of insufficiency varies from Forest to Forest. It should be noted that estimates of current and future losses in timber volume and other resource outputs were not widely available during development of the Forest Plans. As a consequence, allowable sale quantity, Habitat Capability, and other calculations may not have accurately taken into account pest-caused losses nor the risk of these losses occurring. Also note that much of this type of information is still not available; however, aerial insect survey data and intensive insect and disease-caused loss evaluations do go some distance toward offsetting that lack.

Growth and yield models have been used for quantifying resource outputs, and evaluating alternatives. However, available growth and yield models have lacked the ability to simulate many pest-caused impacts. Much of the modeling work in recent years has involved designing and calibrating models that assess pest impacts. Only a few of these pest models were available during the early stages of planning for the current set of Forest Plans. Thus, the Forest Plans did not project the levels of resource loss that are occurring.

A major emphasis needs to be placed on monitoring our ability to meet the Standards & Guidelines and Desired Future Conditions of the various Forest Plans. Where conflicts arise between the on-the-ground actualities and the goals of the Plans, the Plans should be reviewed for possible revision, and the treatments being used should be examined for possible alterations.

The primary forest pest models that are available for use in the Blue Mountains include:

1. The Western Root Disease model, designed to work with PROGNOSIS, currently incorporates laminated root rot and Armillaria root disease. Annosus root disease will soon be added. Simulating root disease impact requires extensive training and has generally been done by only a few experienced PROGNOSIS users.

2. Dwarf mistletoe growth reduction and intensification equations have always been a part of the basic PROGNOSIS model. Dwarf Mistletoe Ratings (DMR's) are automatically read from plot tree records. The dwarf mistletoe impact facet of PROGNOSIS is currently being improved to simulate mortality and more accurately estimate growth impact and spread.

3. Western spruce budworm populations and damage can be simulated with three existing programs. Two of these are PROGNOSIS extensions: A Budworm Dynamics Model, and a Budworm Damage Model. The third is a budworm

population dynamics model with no linkage to PROGNOSIS. A fourth multi-stand dynamics model is being planned.

4. The Mountain Pine Beetle Model is an extension of PROGNOSIS and can be used to simulate epidemics in lodgepole pine stands.

5. The Douglas-fir Tussock Moth Outbreak Model and Combined Stand Prognosis--Douglas-fir Tussock Moth Outbreak Models simulate the population dynamics of Douglas-fir tussock moth, and the probable consequences of silvicultural treatments and tussock moth control activities for stands, respectively. Improvements to the models are pending.

These models have had limited use in the Blue Mountains. Reasons for the lack of use are not fully known, but one reason is that most models have specific pest data requirements that are not normally collected during the course of routine stand examinations or inventories. A separate, special pest survey is usually needed to collect the information necessary to run the model. Secondly, until very recently, preparing keywords for runstreams for jobs submitted to the Fort Collins Computer Center, Ft. Collins, Colorado, to make PROGNOSIS runs with the pest-model extensions, was not easy to do. However, the recent development of a simplified pest model submittal system has automated and simplified the process, making the use of pest model extensions with PROGNOSIS much more "user friendly." This should encourage the use of these models.

National models need to be developed, and existing models need to be more fully incorporated into commonly used stand simulators. For example, we know that true fir stands in long rotations can experience substantial decay-caused defect, but such losses are not currently estimated by any commonly used growth and yield model.

The use of pest models in the planning process to simulate insect and disease conditions, and compare treatment and no-treatment strategies, would greatly improve the ability of managers to take into account the losses and impacts due to insects and diseases, during Forest- or project-level planning. Many new pest models need to be developed for use during the next Forest planning cycle to incorporate pest-induced losses. The Integrated Forest Resource Management System (INFORMS) is one example of how multi-pest models can be integrated with a variety of resource models (and PROGNOSIS) to evaluate multiple effects and interactions of pests and various treatment alternatives on resource outputs, and to examine how the forest environment might be affected in turn.

Planning tools like INFORMS should become more valuable to resource planners in the future, especially after the applicability of INFORMS has been demonstrated by the current pilot test on the La Grande RD.

Forest pests also relate to the planning issue would be in terms of the pest considerations that must be included during the environmental analysis of forest resource projects. Since insects and diseases often adversely affect areas being considered for development or treatment, it is essential to obtain pest specialists' input to inter-disciplinary teams conducting forest resource management planning. For example, it wouldn't be prudent to site a campground in an area where the onsite residual stand would have a high probability of failing during a windstorm due to unacceptable levels of disease. A pathologist's input, both in conducting a thorough biological evaluation for pests and in participating on the ID team, would be imperative in this instance.

Forest pests invariably play a key role in the management of stands, yet rarely are pests considered a priority for management activities. In addition, unless they are apparent, they are often overlooked during project planning and analysis stages. As illustrated in the example above, achievement of resource objectives for an area may be thwarted by an unseen pest problem.

Geographic Information System (GIS) technology is becoming increasingly more important as a resource planning tool. Numerous successful demonstrations and applications of GIS technology for resource planning, from insect suppression projects to fire recovery projects, have been made in the Blue Mountains over the past five years. This technology, once fully implemented, will be widely used in project decision support resource analysis, and will serve in ways we barely imagined 10 years ago. GIS is an invaluable development from a pest management standpoint, it is already used by the R-6 Forest Pest Management staff to take data from the annual Aerial Insect Detection Survey and apply it to preparing maps and reports on insect infestations. The database containing insect survey information that is built from the digitized survey maps, is easily transmitted over the Data General computer system to National Forest Supervisor's Offices, where Forest or District personnel can build insect layers to overlay on various other resource layers, and thereby perform numerous analyses or compare project treatment alternatives.

The National Forests of the Blue Mountains are at various stages in their ability to build different layers, such as vegetation and Forest Plan management allocation layers. Once these, and numerous other, layers are available and used in combination with existing insect layers, they will undoubtedly increase by many-fold the variety of opportunities and options available, and the speed with which analyses of resource projects can be conducted. Thus, the efficiency of project- and Forest-level planning should increase significantly with GIS technology. In addition, a number of new GIS products have been described, including several relating to insect and disease, that will be widely applicable by resource managers and planners in the future.

Finally, District-level Forest Health Implementation Plans that address the various aspects of pest management as they relate to resource management activities on Districts, need to be developed and implemented on individual Districts. The Pine Ranger District has recently developed such a plan, which can be used as a model for other Districts (see Appendix B). Implementation of the plan will insure that pest management concerns are addressed in every resource management activity on the District.

Issue 2 - **Public Involvement**

Public interest, awareness, and concern is varied (and sometimes divided) with respect to issues related to Forest Health. Forest health concerns go much deeper than insect and disease infestations, which often are only symptoms of much greater underlying problems. Forest health evolves out of a multitude of interactions among soils, watersheds, vegetation communities, site characteristics, diversity, weather and climate, fire, of human activities, and many other factors. All these work together in complex fashion to shape and modify all forest resources in a way that defines the state of Forest health for the National Forest in the Blue Mountains. However, though all of these other factors are important, the remainder of discussion of this Issue will focus on the relationship of the Issue to the management of insects and diseases, in terms of both prevention activities and suppressing populations when they become forest pests.

The public is acutely aware of insect epidemics. Like forest fires, insect outbreaks are highly visible and often affect the quality of our recreation, as well as, livelihoods of many individuals that live in and around the Blue Mountains. On the other hand, most forest disease problems are ever-present, but much less dramatic and most individuals are probably not aware of their widespread occurrence and propensity for damage.

Management attempts at dealing with pest problems, either by direct intervention (e.g., controlling an epidemic pest problem) or by prevention (e.g., thinning stands to control stocking and improve vigor and resistance to bark beetles) frequently run into direct conflict with the expectations of certain segments of the public. There seems to be a distrust of the forest managers' motives on the part of some of the public. As stated by McIntire (1988):

> "Forest management decisions and practices, appropriate from the perspective of the forester, are often viewed by the public as narrow in purpose and not responsive to broader social goals and values...The public may be skeptical of vegetation management activities for pest control that appear to be conventional commercial timber harvesting operations...The general public does not understand forest ecosystem dynamics or the dynamics of pest outbreaks, and may be further confused by the differing opinions of experts."

Herein lies the fundamental problem: There is a lack of adequate understanding on the part of the public of the rationales used by forest managers to achieve a management objective, and there is a lack in our ability (or efforts) to effectively communicate those objectives in relation to the intricate processes of the forest ecosystem. It would therefore seem that the successful implementation of any recommendations to restore and maintain Forest Health depends upon our ability to effectively communicate to the public the nature and scope of the problem, and the realities of continuing forest ecosystem decline in the absence of sometimes bold, and perhaps unpopular, management actions.

Central to the Forest Health issue are several points that need to be shared with the public. These include the following:

1. At least 90 years of fire suppression have changed the character of our forests from their previous "natural" condition.

2. Selective harvesting was the established harvesting technique in most timber types from the time the first trees were cut in the Blue Mountains until the early 1970's. A high proportion of the more valuable pines, larch, and Douglas-fir have been removed leaving many stands dominated by, and regenerating back, to true firs. While we now commonly refer to this selection harvesting as "high-grading," it probably was considered an improvement or sanitation technique at the time. Entomologists recommended removal of low vigor ponderosa pine to minimize western pine beetle activity, but this technique was sometimes misused. Economics also played a role, especially with regard to associated species. Low values of true firs often greatly limited the options for removing them in sales.

3. Wildfire hazards have increased. Build-up of fuels, development of fuel ladders, increased stocking, and increased numbers of pest-killed trees coupled with natural occurrences of drought, have predisposed large expanses of forested land to catastrophic wildfire. The Wallowa-Whitman and Malheur National Forests have each had several catastrophic fires in recent years. These catastrophic stand-replacement fires appear to be increasing both in size and frequency in modern times; whereas in the past, conflagration fires in Blue Mountains grand fir communities occurred at intervals varying from 50 to 300 years.

4. Most resources have been affected by changes to forest ecosystems wrought by selective harvesting and exclusion of fire. The results are systems that are less stable and more susceptible to catastrophic fire and pest-caused damage. Resources and values that are adversely affected include:

- Visual quality,
- soil qualities,
- wildlife forage,
- timber value,
- forest Health,
- maintenance of old-growth stands,
- water quality and watershed condition,
- seed sources of seral species and silvicultural options,
- seed production, and
- riparian communities

5. Disease-caused losses are often similar in scope to those caused by insects. Generally, such losses are less noticeable because they occur over such long periods of time, but often have extensive adverse effects on resources nonetheless.

The reality of the influence of pests on Forest Health in the Blue Mountains needs to be emphasized to the public. Several main points need to be conveyed: (1) Long-term problems will usually require long-term solutions. There are few "quick fixes;" (2) reasons should be given before the Forest Service undertakes certain activities, especially those that are perceived by the public with scepticism (eg. burning, regeneration harvests, road closures, etc.); (3) past management emphasis has been on the short-term timber resource; changes need to be made to enhance long-term goals for all resources; (4) certain actions to restore Forest Health will conflict with non-timber resources in the short-term; (5) the concept of Desired Future Condition; (6) the role pests play in stands that have been selectively logged; and (7) the role of fire in the ecosystem.

Forest pests affect the various management allocations and objectives of the Forest Plans in so many ways that nearly every segment of the public is affected to one degree or another. The ability to achieve Forest Plan direction concerning the Desired Future Condition for various resources is being challenged by the current state of health of the Blue Mountains. However, close involvement with the public will play a critical role in successfully implementing Forest Health recommendations that will enable the Forests to meet the Desired Future Condition in the long-term, and restore and maintain Forest Health in the Blue Mountains.

Issue 3 - **Resource Management**

The ability to manage the National Forest resources of the Blue Mountains to meet multiple-resource outputs and achieve the Desired Future Conditions described in the Forest Plans will be an enormous challenge for the Malheur, Umatilla, and Wallowa-Whitman National Forests over the next decade. Current Forest conditions such as the continuing decline in overall health of the Forests, the probability of future conflagrational wildfires, and episodes of catastrophic insect- and disease-caused losses, significantly add to the difficulty in meeting Forest Plan objectives. This is especially true where the need to achieve certain resource management objectives runs into conflict with the need to manage for Forest Health.

A number of current management practices and resource trade-offs aggravate forest pest problems. We have already mentioned in a number of places how past practices of fire prevention and suppression, and selective harvesting of the economically more valuable species have altered the biological diversity, impacted productivity, damaged watersheds, and promoted many significant pest problems. Other practices used to meet goals such as: Wildlife habitat and cover objectives, old-growth requirements, viewshed management objectives, and protection and enhancement of riparian areas, have oftentimes encouraged species composition and stand conditions (primarily, over-stocking, multiple canopy layers, uneven-aged conditions, and large proportions of true fir stocking), that promote serious pest problems. Frequently this results in catastrophic levels of mortality, and sometimes compromises the management allocation objectives and ability to achieve the Desired Future Condition for a given resource.

If we continue along the current course towards meeting resource management allocation objectives without incorporating pest or fire prevention, we ignore the potential for fire- and pest-caused catastrophies of significant magnitude to occur at some time in the future. Stands in non-timber allocations that are conditioned for defoliator and bark beetle outbreaks and those exhibiting symptoms of susceptibility to forest diseases are of particular concern. Many insect outbreaks cause dramatic increases in mortality (and other damage) to trees over a short-term. Usually, such outbreaks are followed by a collapse of the insect population to undamaging, endemic levels; whereas, disease problems such as root disease continue to operate on a site for many decades, slowly and insidiously expanding centers of infection, causing tree mortality and reducing host vigor so that infected hosts are either killed directly or become targets of bark beetles at some point of time in the future. Such situations critically affect our ability to implement Forest Plan direction for resource allocations. In some cases, the stands may satisfactorily meet the management objective at the present time, but given the present composition and condition of these stands, the quality, character, and condition of these stands may worsen with time and seriously jeopardize the ability of these areas ever to fully meet or maintain the Desired Future Condition.

From a management standpoint, these non-timber resource allocations are of very high concern because it appears that short-term objectives for the resource that are satisfactory (or even marginal) in terms of Forest Health at the present time, are overriding the need to adequately manage the stands for *long-term* Forest Health. Without specific management practices aimed at pest prevention, it is probable that pest occurrence will not be eliminated or reduced on these allocations in the Blue Mountains, nor will we likely achieve Desired Future Condition as set forth in the Forest Plans.

The following few pages highlight many of the ways forest insect and disease pests interact with the various resource management allocations, and outline the results of pest impact on those resource outputs. Most of these pest impacts were recurring observations and concerns expressed by District staffs.

Timber - The timber resource is affected in a number of ways: Direct mortality, which causes wood fiber volume losses such as a decrease in the availability of saw-log material available for sale, and a reduction in future crop trees and growing stock. Growth reduction, stem deformity, and degradation decrease future harvest volume, and lowerlog value and log quality, and reduce recovery potential. Losses of seed sources and seed crops may affect the genetic base, and a shortfall in seed could affect potential supply of new trees available to reforest cut-over or burned-over areas in the future (larch seed is already in short supply). Also, tree losses from pest epidemics leave some areas in under-stocked or non-stocked condition, necessitating artificial regeneration. Pest outbreaks decrease the quality and quantity of sawlogs in timber sales. Together, silvicultural opportunities are diminished as portions of the stand components are killed and also following selective harvesting of overstory pine, larch, and Douglas-fir. Stands lose adequate species constituency, and seral seed tree and shelterwood options disappear. Therefore, pest-caused losses and effects will either directly or indirectly influence the Allowable Sale Quantity (ASQ).

Wildlife - Some insect and disease pests kill so much of a stand that the result is an area that no longer meets visual, riparian, old-growth, and wildlife objectives, thus destroying the stand structure necessary to meet the Desired Future Conditions. Big game cover is lost, especially from defoliation by insects, but also from other insect and disease pests. Along with this loss of cover come impacts on the ability of animals to thermoregulate, escape and hide, and breed and birth undisturbed. Past harvest activities (including both partial cut entries and salvage, overgrazing by domestic livestock, and road construction) and the absence of fire have severely altered both summer and winter ranges.

The main detrimental effects of this are the opening up of greater areas, the disturbance of animals, and changing the species composition and quantity of available forage. Pest problems that develop in one area place greater risk of being affected by pests in the future on adjacent stands. Oftentimes, this is exacerbated by the fact that adjacent stands are equal in susceptibility to the pest-damaged area. Some stands at risk currently qualify as marginal or satisfactory cover, but when pest problems develop in these stands, they may reach levels of damage which place them below cover standards. On the positive side, some pests such as certain dwarf mistletoes, may actually enhance habitat for certain bird species (e.g. great grey owl) that utilize these brooms for nesting, feeding, and roosting (Bull and Henjum 1990). Similarly, some snags created by insect or disease pests provide habitat for snag-dependent species. Also, the opening up of stands can benefit wildlife by increasing the intensity and distribution of light to the forest floor, which promotes the growth of various forage or browse vegetation.

Riparian Areas - Riparian areas are affected in several ways by forest pests. Reductions of cover and stream shading are major influences of pests on riparian areas. Loss of cover diminishes wildlife habitat below desirable levels. Greater solar insolation of streams increases stream temperatures, degrading the habitat for fish. Many riparian areas of the Blue Mountains are stocked predominantly by grand fir and Douglas-fir. They are characteristically overstocked with multiple canopy layers; thus defoliating insects will continue to have an adverse effect on these areas. Stream ecology would benefit by some increases of woody debris, which creates diversity of stream habitats. Large woody debris in streams would enhance pooling, rippling, and hiding and feeding habitats for fish and aquatic macroinvertebrates. However, a fire, following defoliation, could destroy a riparian site. And while it is true that mortality and dead woody material increase following an epidemic, the negative effects of loss of cover and loss of stream shading below desirable levels far outweigh the benefits derived from the increases in snag habitat and down woody material.

It will likely require several decades for vegetation to recover to pre-outbreak levels in pest-impacted riparian areas. Providing for a species mix favoring seral pines and larch during restoration phases of riparian areas would help prevent future damage of these areas by pests. On wetter sites, however, it is best to provide the mix of those site-adapted species that would do best and historically belong on those sites, including grand fir, subalpine fir, and spruce.

Viewsheds and Recreation Areas - The effects of pests on viewsheds and recreation areas include degrading the quality of these sites and the creation of hazards to the public using these areas. The loss of foliage by defoliating insects creates a negative visual impact. Where defoliation has been severe, there is an increased probability of bark beetle-caused losses, as well as threat of wildfire. Both factors heighten the risk of losing use of these sites altogether. Also, there is a much greater safety concern to the public due to the presence of dead trees within reach of roads, campsites, and structures.

Viewsheds affected by bark beetle epidemics tend to experience losses of the large-tree component, because bark beetles often attack these trees first. A loss of the large-tree component would result in a noticeable reduction in the structural diversity of viewsheds. But in some cases, the visual diversity might be improved because of the openings created. Composition and structure of stands would change following a beetle epidemic. In time, the openings created would be revegetated by other plant species whose requirements for increased light are favored by such openings.

Watersheds - Watersheds are also negatively affected by pests. The effect of pests on watersheds can be indirectly manifested through the damage of harvesting and road building activities to recover pest-caused tree mortality. These effects are evident in changes in stream sedimentation, and quantity and timing of streamflow peaks. Soil compaction, disturbance, and displacement from ground-based harvesting equipment during salvage operations have probably resulted in significantly more damage to watersheds than any direct influence of the pests themselves. Multiple entries of stands for partial-cut harvests, commercial thinning, and salvaging operations have caused cumulative damage to watersheds that will not be easily or quickly reversed. The lowered productivity of many of these sites is expressed by poor tree growth and difficulty in re-establishing vegetation following harvests or other deforesting events. Without some type of drastic intervention to treat stands that continue to be plagued by periodic pest epidemics and fires and rehabilitate soils damaged by years of abuse, watershed health and Forest Health will continue to decline.

Fire - Finally, the risk of wildfires is increased due to pests. Catastrophic fires can quickly spread through standing dead, multiple-layered canopy stands following ignition. The thickets of large woody fuels that accumulate on the ground as trees killed by pests fall over significantly increase the risk of hot fires that can seriously damage forest soils, affecting the productivity of sites for years to come. Fires, like insect outbreaks often involve large areas, irrespective of administrative boundaries or management allocations.

However, even though the detrimental effects of forest pests on resource values, outputs, and Desired Future Conditions are recognized, a number of barriers exist that prevent adequate treatment of pests.

A lack of adequate funding to carry out certain silvicultural activities is one of the biggest barriers to providing rehabilitation, restoration, and pest resistance to stands. Timber harvesting, sanitation, and salvage activities sometimes result in removal of timber of such limited volume or value, that Districts cannot collect enough K-V (Knutson-Vandenberg Act) funds to adequately rehabilitate and restore pest-damaged stands to a healthy condition. In other cases, stands in serious need of thinning will not generate these revenues for years in the future. Thousands of acres of second-growth ponderosa pine stands have developed to overstocked condition in many areas throughout the Blue Mountains, usually because effective fire prevention and suppression have prevented natural thinning of stands by light surface fires. These stands, besides being at high-risk to bark beetle damage, in some cases contain unacceptable levels of mistletoe or have other disease problems requiring treatment. These stands are often too young (and of insufficient size) to warrant a commercial entry in which KV monies could be generated and made available to improve stand conditions. Without adequate funding for stand-tending and precommercial thinning, these stands may be left untreated, or only partially treated, and will continue to grow slowly because of overcrowding, and suffer growth loss, other damage, and mortality from pests. A lack of markets for small-size material recovery and utilization opportunities has also been responsible for much wood fiber, considered sub-merchantable, to go unused.

Failure to consider forest pests when prioritizing or scheduling projects can also encourage pest-related losses. Pest management issues are not always considered when deciding the priority and timing of stand treatments and harvests. At times, this has led to serious adverse consequences because stand conditions were ripe for pest outbreaks but warning signs were ignored. Though managers recognize the need for stand treatments to avoid or diminish pest-caused losses and damage, other factors often influence decisions. These factors sometimes prevent the timely treatment of problem areas and can lead to significant pest-caused damage to the resource.

Issue 4 - **Pest Prevention and Suppression**

Pest prevention and suppression considerations need to be elevated to a much higher level of importance in all management activities. Insects and diseases are a natural part of forest ecology when they occur at endemic levels they provide benefits to many resources in the Blue Mountains, but when human activities and processes fail to mimic the natural events that shape and define the vegetation conditions and character of stands, nature may intervene on its own behalf, through pest epidemics and catastrophic wildfires, to correct the unnatural state. Many times the prevention of pests is as simple as implementing any of several silvicultural options which emulate events of nature. Such practices encourages growth and vigor through proper stocking control and spacing, and favor species resistant to pests and those best adapted to the site. But, when stands in non-timber (and sometimes timber) allocations are planned for meeting some level of resource objective, resource specialists and managers are sometimes reluctant to allow silvicultural activities and methods to be fully used. Many areas that are in bad shape from a pest management and silvicultural standpoint, are prevented from being treated because they currently provide benefits in the way of a particular resource being managed for, at least in the short-term.

The passage by Congress of the Forest Pest Control Act in 1947, focused on detection and control of forest insect and disease outbreaks. A funding process was established for pest suppression activities, and a "pest control" mentality soon emerged. The early attitude that insect outbreaks needed to be "controlled" was pervasive throughout the agency, but some began to question the wisdom of treating every outbreak.

While recognizing the importance of the need to avoid wholesale losses of timber volume from timber producing areas, various resource specialists were less certain about the effects of insects and diseases on non-timber resources. Hence, the need arose to consider alternatives to suppression projects, including considering "no-action" alternatives. This was reinforced by legal mandate with the passage of the National Environmental Policy Act of 1969.

Pest suppression is a costly undertaking and its results are short-lived. While reducing immediate damage from pests, suppression does nothing to alter or eliminate the conditions which make stands susceptible to pests in the first place. Few would disagree that long-range pest prevention practices are desirable, but use of silvicultural procedures to accomplish pest prevention is usually not a viable option during the height of an insect epidemic. The length of time required for stand improvement activities to be implemented, and the even larger time needed for trees to express increased vigor and resistance, usually preclude the use of silviculture as a suppression tool.

In considering stand improvement activities on National Forest lands, a major objective must be the long-term prevention of insects and diseases from developing to outbreaks in stands. Clearly, this needs to become established as a routine management practice in all Forest- and project-level planning, not just for timber emphasis areas. The difficulty arises in funding these activities, especially for non-timber resource emphasis areas. Suppression funding cannot be used for prevention work, and many resources (sometimes including timber) do not generate adequate revenues for effective stand improvement work for the purpose of pest prevention. It is possible that if "up-front" funding were available to implement stand improvement projects, with the major objective being the prevention of insect or disease outbreaks, costs of suppression of pests might be reduced or better used in the future. Hence, it seems that a process for funding pure pest prevention work on National Forest lands, and other ownerships is needed.

Limitations on FPM suppression dollars and poorly chosen priorities for their use sometimes impede implementation of certain types of suppression activities which would normally help to prevent additional deterioration of Forest Health. Dwarf mistletoe suppression funding to Districts has been on the decline because much of the control work is accomplished through various other types of vegetation management projects. However, there are cases where this is not adequate to accomplishing effective dwarf mistletoe suppression; in such cases suppression dollars are needed. Some individuals have voiced frustration that, since annual requests for dwarf mistletoe suppression funding have so often been denied (especially during periods of spruce budworm or other insect epidemics, which seem to have funding priority), that the situation has stopped them from requesting suppression funds. Others have indicated that they have had funds, which were distributed for mistletoe control work, pulled back in order to pay for suppression of western spruce budworm.

The traditional method of evaluating insect suppression priorities has been to conduct the economic evaluation portion of the environmental analysis on the basis of timber economic effects. It is much more difficult to calculate non-timber economic effects, so in situations where issues, concerns, and management objectives are primarily for non-timber resources, a qualitative discussion of effects is often all that is possible. Because of this, many non-timber resource areas that are affected by insect epidemics are not offered for treatment consideration or do not compete effectively with those that have timber management objectives. It seems that some of these resources are treated only when there is sufficient public outcry and political pressure in response to pest damage. Although it would be best to improve the resistance to pests of these areas by favoring early seral components in stands, or converting stands over to early seral species, this option may take a long time to implement, and without short-term treatment there is a great risk of losing the value that foliated trees provide to the resource. Thus, there will be times when treatment of these non-timber resource areas with pesticides, is appropriate.

All too often, we spend an enormous amount of time in deciding where it is that we want to apply treatments for pests, after outbreaks occur. Information that needs to be considered for the treatment of pests is scattered among various places, e.g., Forest Plans, vegetation maps, resource project plans, historical records and reports, Annual Aerial Insect Detection Surveys, biological evaluations, resource specialists, technicians, managers ad infinitum. It seems much more prudent, efficient, and expedient, to decide beforehand where and how pest treatment is most appropriate. The technology, methods, and resource planning tools exist, or could be developed, to accomplish this objective. Geographic Information Systems, pest and resource models, and risk- or hazard-rating systems are tools that could help in this preemptive approach.

Sometimes, impediments to timely accomplishment of pre-suppression and suppression activities are the lack of available, qualified individuals. Past experience has shown that even when the Incident Command System has been utilized within the Region to "Resource Order" qualified individuals for details to work on an insect suppression project, some unit managers or supervisors have been reluctant to release individuals from their responsibilities on their home Districts at the particular time, or for the period of time needed. It seems that insect suppression projects do not generate the same sense of resource concern and urgency among resource specialists and managers that wildfires do.

There is a current thrust to implement more unevenaged management systems in the National Forests of the Blue Mountains in the future. It is not clear that resource specialists and managers, and especially the general public, fully realize the pest management implications of doing this within the differing vegetation series and plant associations occurring in the Blue Mountains. In fact, one of the reasons the Blue Mountains has been experiencing devastating and recurring western spruce budworm outbreaks is that stands composed primarily of shade-tolerant true fir, but also Douglas-fir, have developed in an unnatural condition and now approximate, to various degrees, an unevenaged or all-age managed stand with shade-tolerant budworm host species at all canopy levels. A separate section in the appendices contains a brief discussion of unevenaged management and associated forest insect and disease pest problems.

Issue 5 - **Environmental Analysis**

Programmatic NEPA documents that could be used to simplify project-level NEPA analyses and shorten response time to pest outbreaks are not available for all major catastrophic events that occur in the Blue Mountains Forests. If they were available, such documents would then be ready for tiering or incorporation into site-specific Environmental Assessments.

A natural catastrophe like wildfire elicits rapid response by agencies because of the significant risk of loss to resources, property, and human life. Catastrophies other than fire, though they appear less immediate, should be considered on an equal plane with fire when it comes to the need to respond rapidly to prevent or minimize losses. Right now though service-wide competition for a limited pool of forest pest suppression dollars, and delays in distribution of those dollars, impede Forests' ability to rapidly respond to catastrophic pest problems.

Issue 6 - **Pesticides**

The preferred management approach to forest pests in the Blue Mountains is the use of integrated pest management strategies and techniques. The integration of pest management with forest resource management to meet different resource management objectives is a dynamic and challenging process. And the process will become even more so as more information becomes known about forest pests and their interaction with (and impacts on) host trees and stands, the dynamics of forest ecosystems, the changing levels of resource emphasis, outputs, and management, and changes in pest management and control technology. Progress has been slow, but we have come a long way in our knowledge of the management of all forest pests since the establishment of the National Forest System. The need to effectively detect, evaluate, and suppress damaging pests that threaten the Forests is becoming increasingly more important for forest resource managers. With the advent of DDT in the early 1940's, and its effectiveness against defoliating insects, resource managers and entomologists began to feel secure in the fact that outbreaks of these defoliating insects could be quickly suppressed. This, and other chemical insecticides introduced later on, provided an easy solution to major pest problems, and encouraged reliance on chemical pesticides for management of insect problems.

Plant pathologists have been much more effective in developing non-chemical means of managing disease problems; these are largely silvicultural methods such as species manipulation. This is partly because disease infestations generally grow more slowly than insect infestations. Diseases are much less dramatic, though equally damaging, in their effects and impacts on forest trees and stands. Entomologists, too, have effective non-chemical options, but these are generally directed towards prevention of pest problems or taken as remedial action. Chemical insecticides were heavily used in forest pest suppression as late as the early 1980's, and were viewed as the best, and sometimes only, method available for insect control in this Region.

Successful insect suppression efforts using entomopathogenic bacteria and viruses and behavior-modifying chemicals have promoted a greater reliance on biological methods of controlling outbreak populations of insect pests; while introduced-parasite releases, silvicultural methods, and other approaches have been employed in managing various pests populations in an integrated approach. One major advantage of using biological agents such as semiochemicals and microbial agents as opposed to conventional pest-suppression chemicals, is their environmental safety. These agents have varying properties which include such benefits as being non-polluting, biodegradable, and having virtually no non-target side effects.

However, certain special situations, such as a grasshopper epidemic, which may threaten complete loss of trees in a newly-planted seed orchard, may have such high value that we can't afford to wait for non-conventional chemical methods to bring about decline of population numbers. Prompt action with a chemical treatment would be advised under this circumstance.

In the majority of cases, pesticide treatment of insect outbreaks is only a short-term solution to a pest problem. Treatment with pesticides and use of pheromones does nothing to alter the stand conditions that promote pest problems over the long-term. Hence, while short-term solutions are needed at times, only those actions which address the problem over the long-term will enable Forests to meet the Desired Future Conditions for the resources being managed. The integrated pest management approach will have to be tailored to fit management objectives if we are to effectively manage Forest resources in the Blue Mountains for the resource outputs defined in the Forest Plans. Therefore, it will be critical to determine the precise combination of pesticides and non-chemical treatments that will best serve the resource management objectives and provide both short-term and long-term solutions to Forest Health in the Blue Mountains.

Issue 7 - **Pest Suppression Technology**

Pest control technology is in a continual state of evolution. It is imperative that Forests of the Blue Mountains have access to the state-of-the-art technology regarding pest suppression and pest management options and recommendations. Zone pest specialists play a key role in this technology transfer.

Information exchange is crucial between various headquarter units and field units. Coordination and transfer of information and technology to pest specialists, and ultimately to resource specialists and managers at field units, occurs at both the Regional Office (Forest Pest Management) and at the Pacific Northwest Research Station (Forest Health Research, Development, and Application Program). The Blue Mountains Natural Resources Institute and various western Forest Service Research Stations may also provide this technology directly, but the Regional Office generally serves as a clearinghouse for this information.

With the on-going development of and interest in, environmentally-safe and acceptable pest management tools (such as microbial-based insecticides and use of parasites and predators), managers have a broader array of short-term pest management strategies than existed in the past. While it is most desirable to rehabilitate stand conditions and areas that are at high-risk to damage by insects, it is impossible, not to mention undesirable, to eliminate insect-caused damage altogether. Periodic outbreaks of insects will occur regardless of the silvicultural practices employed, or how intensively stands and forests are managed. It is important to have in addition to chemical options, effective short-term microbial-, semiochemical-, and other biological-based strategies available to deal with these outbreaks, when they occur.

Tremendous strides have been made in the use of semiochemicals to manipulate insect populations to achieve desired results. Yet, the application of these tools in an integrated pest management program is still in a state of infancy in this Region. The use or testing of these tools in various pest management strategies, as well as the development of others, needs to be encouraged and supported to bring these various techniques into full operational usage in the Blue Mountains. Manipulative, short-term pest suppression methods can also be used to protect values other than timber. The use of these methods to protect wildlife habitat, riparian zones, recreational areas, viewsheds, and others needs to be demonstrated so that their use will be both encouraged and supported in the future.

Recommendations need to be perfected for Black stain root disease, spruce weevil, bait and cut strategies for bark beetles, and others. As more pest management and control information on these pests becomes known, it will be incorporated into Forest- and project-level planning. These changes could influence Forest Plan Standards and Guidelines.

Opportunities for cooperative efforts between National Forests, Forest Pest Management, and Forest Service Research need to be identified, and funds need to be made available to carry out those studies, demonstration projects, and field or pilot tests that will have greatest applicability to on-the-ground pest problems faced by resource managers. The effectiveness of new technology implemented on an operational basis needs to be monitored for effectiveness beyond the duration of treatment. Funding this type of monitoring activity has been a problem in the past. Pest management actions and strategies employed on Forests or Districts need to be given the same followup funding support that many timber-related activities are afforded as part of the normal District timber or silviculture programs.

Issue 8 - **Forest Health Monitoring**

Monitoring of insect and disease levels and stand conditions conducive for pest buildup and outbreaks is extremely important so that analysis, adequate planning, and action may be promptly taken to avert unacceptable resource impacts.

The Current monitoring program includes:

A. Annual Aerial Detection Survey is implemented by Forest Pest Management (FPM) in the Regional Office. This survey is done Region-wide by trained observers in fixed wing aircraft. Outputs are: Identification of damaging pest (usually defoliating insects and bark beetles), location and severity of damage, and a listing and estimate of loss per administrative unit. This survey cannot provide disease loss information, most current year beetle-caused mortality, or other pest damage not apparent from the air.

B. Pheromone are set for Douglas-fir tussock moth and western spruce budworm. These two types of traps are provided by FPM- Regional Office to individual Ranger Districts. Traps are placed in established plots which are representative of the host types on that District. Traps are placed in the field prior to the adult insect emergence. Following the insect flight, traps are collected and read by trained District personnel or returned to FPM. Pheromone traps normally catch only a few insects, which is representative of an endemic population. Pheromone trapping provides an early warning system for a build up of tussock moth populations. An early-warning system for predicting budworm defoliation through the use of pheremone- baited traps is currently under evaluations in this, and other regions.

C. Larvae or cocoon sampling is usually done in cases where a building population of tussock moth or budworm is suspected, or where a known population exists and suppression is being considered. Larval sampling can also be done during suppression projects to monitor insect development and to determine effectiveness of treatment. Larval sampling is done for both spruce budworm and tussock moth during the summer when they are feeding. Tussock moth cocoon sampling is done in the Fall. The cocoon sample can be used to predict early larval population levels in the spring.

D. Informal monitoring of pest occurrence, damage, and stand conditions conducive for pest buildup (e.g. windthrow), is done by District and Forest personnel as a part of their normal work activity. Silviculture and Timber staff and their field crews, especially stand examination and marking crews, often monitor pest trends, are aware of building pest populations, and spot initial damage.

E. The Zone Entomologist and Zone Pathologist are alerted early-on to most pest situations as part of their jobs. Interactions with Forest and District staffs, functional assistance trips, biological evaluations, and training and workshop sessions with field crews all provide for information sharing. Where a potential for pest impacts is determined, District staff are alerted and provided with background information and assistance.

Monitoring plans for pests may need to be refined in the Forest Plans. Procedures for monitoring pests and stand susceptibility are not fully developed. Forests health monitoring standards, criteria, procedures, and tools, are generally lacking. Monitoring tools, such as lower crown larval sampling procedures and pheromone trapping of adult male moths are available to help monitor defoliator populations. Some trapping techniques using pheromones are also available for monitoring bark beetles. However, protocol for monitoring these forest insects, as well as for diseases and other Forest Health parameters, are not yet developed. The Regional Office will need to keep Forests apprised of developments in Forest Health monitoring at the National level. Funds must be made available to accomplish Forest Health and pest management-related monitoring. Both the Blue Mountains Natural Resources Institute and the Forest Health RD & A Program of the PNW Research Station can help facilitate the development and implementation of Forest Health monitoring plans in the Blue Mountains.

Issue 9 - **Coordination**

Forest pest problems frequently cross administrative and ownership boundaries. Similarities in stand condition, species composition, fire suppression, and partial cut harvest patterns over wide geographic areas of the Blue Mountains combine to create stands which harbor pests, and may foster periodic buildup of pest populations epidemic levels.

Efforts to coordinate certain pest management activities such as suppression programs have been variably successful in the past and should be encouraged in the future. Sometimes different resource objectives between adjacent landowners or resource managers create barriers to implementing activities that promote Forest Health on National Forest Service lands. Better ways of communicating Forest Health needs and objectives, and coordinating plans and programs which address Forest Health concerns in a manner sensitive to all resource managers' concerns and objectives should be considered to be a high priority for National Forests in the Blue Mountains.

Since pest management activities (e.g., treatment of defoliator outbreaks) may involve entire watersheds containing a mix of federal, state, and private ownerships, it is important to adopt a "watershed perspective" when dealing with pest problems. A coordinated effort between various agencies, industries, organizations, and individuals is will be needed to accomplish pest management actions and resource management objectives. Across-the-board coordination and cooperation will become increasingly more important if we are to successfully implement recommendations and actions aimed at restoring and maintaining Forest Health in the context of Forest Plan resource management goals.

Issue 10 - **Role of Fire**

There are several points to make in regard to forest pests and the role of fire in the ecosystem. Most importantly, it should be noted that the role that each plays in the forest ecosystem inevitably influences the other. Fire has an extremely important role in defining the vegetation of an area. The composition, density, structure, and degree of susceptibility of stands to forest insects and diseases all turn on the question of fire. On the other hand, Forest pests by damaging individual trees, groups of trees, or entire stands, have a direct influence on the intensity and frequency of fire. High levels of pest-caused dead and dying trees and dead foliage, when coupled with an accumulation of fuels and fuel ladders resulting from years of fire prevention and influenced by several years of drought, all predispose stands and forests to major risks of conflagration fires.

Wright and Heinselman (1973) have summarized some of the pest/fire relationships in the following:

1. Fire directly terminates outbreaks of the spruce budworm, mountain pine beetle, and other insects, by eliminating their hosts over sizable areas.

2. Fire or the lack of it regulates the total vegetative mosaic, and the age structure of individual forest stands within it. These influence insect populations.

3. Insect outbreaks may create fuel concentrations that make large-scale fires possible. Such fires then terminate the outbreak until the stands again attain susceptible ages. A self-perpetuating interaction may occur.

4. Fires temporarily eliminate such plant parasites as mistletoe on black spruce, lodgepole pine, and perhaps other species. It may also "sanitize" forests against other pathogens for a time. (We know little about such interactions yet.)

It is widely believed that much of the degradation of Forest Health in the Blue Mountains is directly related to effective fire suppression during this century. Loss of naturally-occurring light ground fires has increased structural diversity but reduced overall stand diversity, diminished the occurrence of natural stands of adapted seral species best suited to certain sites, and destabilized vegetation composition and stand structure by allowing overstocked, multi-layered, shade-tolerant species to proliferate. Stand conditions that at one time would have supported only light ground fires due to the maintenance of light fuel loads are now predisposed to catastrophic fires because of the presence of excessive fuels. Most stands would need some type of silvicultural treatment to reduce fuels prior to re-establishing fire.

The benefits of light ground fires are numerous: (1) Fire maintains forests in more diverse, yet younger successional stages. Early seral species are less susceptible to pest-caused damage; (2) fire can be used to increase mushroom hunting opportunities; (3) fire can be used to enhance wildlife forage; (4) fire can accomplish a number of silvicultural tasks easily and cheaply; (5) fire can be used to maintain old-growth forests in a healthy condition; (6) ground fires will reduce cover in the short-term, but may increase cover in the long-term by lowering catastrophic wildfire hazard; and (7) fire can be used to sanitize stands of dwarf mistletoe-infested understory. Smoke also has a detrimental effect on dwarf mistletoe plants and seeds.

The Forests in the Blue Mountains need to return to a fire regime of the type that was once a part of the natural processes which shaped and maintained vegetation communities on the forested landscape. This is one of the most critical actions that can be taken by managers to restore and maintain Forest Health. As Forests increase the use of fire on National Forest lands, public involvement and coordination with various groups, agencies, and governing bodies will be an important part of the process of resolving the inevitable controversial issues that will arise over air quality and airshed management.

Issue 11 - **Biodiversity**

Generally, the more diverse plant communities are healthier, and, therefore, are less susceptible to catastrophic pest-caused damage. In most cases, ecosystem health can be improved by increasing diversity. It is critical to understand that there are different types of diversity, and some situations (diverse by some measures) are especially susceptible to forest pests. On one extreme, the monoculture is a species-impoverished, unstable condition which has limited richness in terms of plant and animal species and habitats. It may also be especially vulnerable to a particular pest for which it constitutes the favored habitat (e.g., western spruce budworm damage in a pure stand of overstocked, multistoried grand fir growing on a warm, dry site). The stand described in this example, on the other hand, can be said to have a very high degree of structural diversity because of the multiple-layered canopy structure. And purely in terms of this measure of diversity, we might be tempted to say this was desirable, but from a pest management point of view, this is indeed highly undesirable considering the high probability of budworm-caused damage to understory tree components. There needs to be a balance between what is desirable from the diversity side, and what can be tolerated from the pest management side. If we are to restore and maintain Forest health in the Blue Mountains, it is imperative that we manage stands to avoid situations which would lead to pest problems in the future. This may mean sacrificing some forms of diversity in the short-term to achieve long-term benefits.

It is important, too, to recognize the important roles that insects and diseases can play in enhancing biological diversity. Plant communities have co-evolved with native insects, diseases and fire. Different community components and their relative frequency are in-part determined by these factors. The genetic diversity of these species is also influenced by insects, diseases, and fire. Management strategies should consider these relationships and strive for stability through maintenance of a variety of species and their genetic variability.

The benefits of bark beetles, for example, in creating habitat for cavity nesting species and for improving stream habitats have already been addressed in the introductory section on insects. Insects and diseases help to create visual diversity by breaking up vast expanses of live green canopies in old-growth stands, riparian zones, and viewsheds, through the creation of snags, dying trees, downed woody material, and openings in the canopy. It is possible to artificially encourage some of this diversity through the selective use of certain bark beetle semiochemicals.

Certain Douglas-fir dwarf mistletoed trees are used by grouse species for roosting and feeding activities. Where the influence of some-infected level of mistletoed trees will not be detrimental to timber or other resources, these trees should be retained to enhance wildlife values and promote species and habitat diversity.

Issue 12 - **Long-Term Site Productivity**

The direct effects of insects on site productivity are usually minimal. In the cases of bark beetles and root diseases that kill small groups of trees, the effect on site productivity in timber management allocations may be viewed as one of temporarily taking a small parcel of ground out of production of wood fiber. This is a very different--albeit real--interpretation of site productivity than is traditionally used. The opening created, however, will increase the regime of light on the forest floor and enhance growth and a diversity of vegetation that may be important for forage of wild game and domestic animals.

In the more traditional sense, the direct action of insects may well enhance the site productivity of forested areas. Some studies have suggested that defoliation by insects contributes a significant load of nitrogenous (and other) compounds back to the soil as a result of their feeding activities. Chemical compounds are leached from insect frass (fecal pellets), and deposits of dead needles or parts of needles as they break down, and may enhance the nutrient capacity of the soil. Residual defoliated host trees and non-host species within defoliated stands, has shown greater increases in growth than similar trees in stands where defoliation has not occurred. However, this may also be partially the result of the thinning of stands by insects in defoliated areas, where smaller trees have been killed by the defoliation.

Some of the impact of pests on productivity of Forests in the Blue Mountains may be indirectly linked to the damaging of soils which occurs when ground-based logging equipment is used in making multiple entries to salvage disease- and insect-killed trees. These logging systems have been used for years in the Blue Mountains. In many cases, stands have had multiple entries to extract timber in selection tree harvests, as well as to remove individual or groups of trees killed by insects or diseases. When conducted, especially during the early spring when soils are soft and sometimes saturated by snow melts, significant compaction can result, and soil oftentimes becomes disturbed and displaced by wheeled or tracked vehicles. Over the years, repetition of this type of activity has caused serious damage to soils and impacted the productivity of these disturbed sites. Timing of harvesting and salvage operations, as well as the type of harvesting system to be used, must be carefully considered and weighed against the probable damage to the site. We also need to carefully evaluate ways to use fire and the need to leave some dead and down woody material on sites to enhance both the diversity and productivity of sites--two very important considerations in addressing the health of the Blue Mountains National Forest lands.

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CHAPTER III

WATERSHED MANAGEMENT AND FOREST HEALTH

WATERSHED MANAGEMENT AND FOREST HEALTH

Introduction

Whatever our individual management goals or objectives may be, the basic resources of water, soil, and atmosphere form the foundation of *every ecosystem* we manage. All land managers hear the concern for these primary resources in the mandates that Congress provides by legislation, and in the direction that our publics provide when they review and comment on Forest Plans. Watershed management is instrumental to maintaining the equilibrium of these resources. Because the decisions we make about managing forest health affect watersheds and all of the values associated with them, we must consider those values to be of primary importance in all of our problem evaluations and in every alternative course of action that we propose.

Superimposed on the ecosystem base of soil, water, and air is an interconnected network of resources such as vegetation, wildlife, fish, and recreational opportunity. These resources are what users of the National Forests demand, and they are what National Forest management has historically provided, even though the emphasis of our resource management practices has been product-oriented. For example, if an insect infestation occurs and results in dying or poorly growing trees, our approach has been to conduct salvage operations that recover wood products and suppress insect populations to an extent that prevents further losses. On relatively few occasions has a more holistic approach to management been taken. Because our management philosophy has been product- rather than ecosystem-oriented, there has been little attempt to explore the root causes of infestation and examine the long-term impacts of the treatments we prescribe.

However, land managers now recognize that any potential course of action should be based upon knowledge of primary causes, and should take into consideration ecosystem operation and reaction, particularly in regard to forest and rangeland watersheds. This report is one of the first steps leading to that kind of management.

History

Production of high-quality water in adequate quantities to meet the demands of users has been a primary objective of the National Forest System since its establishment. The Organic Act of 1897 states:

> "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..."

Although founders of the National Forest System soon recognized the importance of healthy forest and rangelands in the production of high quality water, linkages between watershed health and other forest management practices such as timber harvest, road building, and grazing were not (and are still not) well understood. Equally as important as the water issue in the management of the National Forests, are aquatic and riparian-dependent wildlife species upon which a high value has been placed by the public. This is especially true of anadromous fish stocks found in the streams of Northeast Oregon and Southeast Washington and the habitat conditions required to maintain their populations.

Maintenance of long-term site productivity is also a primary objective of National Forest management activities and is reflected in key legislation such as the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), the National Forest Management Act of 1976 (NFMA), and the National Environmental Policy Act of 1969 (NEPA). The NFMA states as one of its objectives:

> ...manage National Forest System lands under principles of multiple use and sustained yield without permanent impairment of land productivity and ... maintain or improve land productivity.

Section 6(E) of the NFMA also states that:

> Where timber harvest from National Forest System lands is proposed, it should be considered only where soil, slope, or other watershed conditions will not be irreversibly damaged and where protection is provided for streams, streambanks, shorelines, lakes, wetlands and other bodies of water from detrimental changes in water temperature, blockages of water courses, and deposits, where harvests are likely to seriously affect water conditions and fish habitat.

Adverse watershed conditions resulting from past and present management activities can severely limit our options for future management of the National Forests. During its first half-century, National Forest System management tended to focus on individual stands rather than on entire watersheds. As a result, timber harvest and road building activities were concentrated in some drainages while others were left untouched. Many watersheds were also overgrazed. Over time it became apparent, both through casual observation and formal watershed monitoring efforts, that management activities were having negative impacts on watershed values and site productivity. Some watersheds experienced deterioration of riparian areas, changes in stream channel morphology, changes in timing and quantity of streamflow, and reductions in water quality (increased sediment and temperature). These kinds of problems are presently common throughout the three Blue Mountain National Forests.

The NFMA requires that the Forest Service analyze and display cumulative watershed impacts during project-level environmental analysis. "Cumulative impact" is the term applied to the incremental effects of an action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such actions. Thus cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 508.7).

For example, peak streamflow, snowmelt, and evapotranspiration are influenced by the amount of a watershed that has regrown to a shaded condition. Therefore, timber harvest, fire, roadbuilding and other processes - all affecting the amount of shade in watershed - have additive effects upon such factors and incrementally alter peak streamflow from what it would be in a pristine watershed.

A stream channel can tolerate, up to a point, the higher peak flows generated by increased cutting in a watershed if the channel is in good or stable condition to begin with. However, increased peak flows in stream channels that are in fair or poor condition can cause continued degradation, and once a stream channel is in a degraded condition, it may take many years to recover. Mathematical models are used to predict peak streamflows in watersheds, and guidelines have been established for determining maximum allowable increases based on stream channel condition. On some watersheds, additional timber management activities have occurred where these guidelines have already been exceeded.

Such past digressions have served to point out the necessity of allowing watershed recovery to occur before new management activities take place.

Current Situation

As demands for forest products of all kinds increase and the land base available for such outputs decreases, the potential for further reductions in watershed health increases. In order to offset these potential detrimental effects, overall watershed health needs to be examined at three levels: Individual forest stands, entire watersheds, and impacts on downstream values.

Individual Stands:

Productivity of individual forest stands is a function of climate (both macro- and micro-climate), site, and soil characteristics such as structure, texture, water holding capacity and fertility. Forest management activities associated with yarding and slash disposal have the potential to modify soil characteristics through effects of erosion, compaction, and alteration of chemical and microbiological processes. In turn, such modifications can increase the stress experienced by a given stand, and subsequently, reduce its growth. Such changes may be obvious or subtle and may predispose forest stands growing on such sites to attacks by insect and/or disease organisms.

Forest management activities can change the way in which a stand receives and distributes water, and both direct precipitation and run-off from adjacent areas can be affected. Changes in infiltration rates and interception of subsurface water flow can result in accelerated surface and mass erosion and increased sediment delivery to stream systems; they can also result in a reduction of plant vigor through simple decreases in water supply.

Some changes may be reversible but only after years have passed. Even when it is possible, rehabilitation is often expensive and may be less than 100 percent effective. Changes in watershed quality that are severe enough as to be correctible only with difficulty may be tolerable only on small portions of individual stands or watersheds. However, the degree of tolerance is still a matter of debate, even as we become increasingly aware of unacceptable kinds and degrees of watershed and soil-related impacts.

In order to meet the intent of NFMA and other key legislation, the Pacific Northwest Region (R-6) of the Forest Service developed direction regarding soil productivity protection (FSM 2500 R-6 Supplement 2500-90--1). This direction states:

> Leave a minimum of 80 percent of an activity area in a condition of acceptable productivity potential for trees and other managed vegetation following land management activities.

This direction essentially establishes an upper limit, or tolerance level, for detrimental soil conditions. Beyond this, there is thought to be unacceptable vegetation growth loss and, therefore, increased stress and vulnerability to insect and disease attack.

Altered soil conditions known to reduce forest productivity include:

Compaction. Compaction of soil increases bulk density and decreases porosity through the application of mechanical forces such as weight or vibration. Compaction damage has been defined in Region Six as an increase in soil bulk density of 20 percent for volcanic ash soils (15 percent for all other soils), a 50 percent reduction in soil porosity, or a reduction in total soil pore space below 15 percent.

Puddling. Puddling is a physical change wherein external forces destroy soil structure. The result is reduced soil aeration and water movement. Puddling generally occurs when soils are operated upon when they are at or above field capacity, and it results in breakdown of soil structure, molding of soil in vehicle tracks, and deep rutting.

Displacement. Displacement is the removal and horizontal movement of soil from one place to another by mechanical forces. Detrimental displacement has been defined as the removal of more than 50 percent of the topsoil or humus enriched A1 and AC horizons from an area of 100 square-feet or more which is at least 5 feet in width. Displacement is a major consideration where skidding or machine piling of slash occurs.

Severely Burned. Soils are considered to be severely burned when the top layer of mineral soil experiences a significant change in color, usually to red, and the next one-half inch is blackened due to organic matter being charred by heat conducted through the top layer. Soils that are severely burned often have reduced nutrient contents and infiltration rates. Associated water repellency of soil layers can lead to extremely high erosion rates.

Surface Erosion. Surface erosion is the detachment and transport of individual soil particles by wind, water, or gravity. It can occur in uniform layers across the land surface, and in such instances it may not be easily observable; it can also occur as many small rills and gullies. Erosion can result in the loss of many tons of nutrient-rich surface soils.

Awareness of these soil-related problems really began in the late 1970's, when Northeast Oregon pine forests were devastated by an infestation of mountain pine beetle. In an effort to salvage large acreages of relatively low-value product, mechanized harvesting equipment such as rubber-tired and track-mounted feller bunchers, skidding machines, limbers and loaders were used. These kinds of equipment affect a high percentage of the ground surface. Concern developed for potential effects on future stand productivity, hydrologic response, and forest health.

As a result of this growing awareness, land managers began to feel a major concern was compaction of forest soils by ground-based harvesting equipment. Several studies conducted in other geographic areas have shown compaction to have significant negative impacts on individual tree and forest stand growth (Froehlich 1979, Wert and Thomas 1981). In a recent study conducted in northeast Oregon, findings showed consistent and statistically significant reductions in tree height and radial growth for lodgepole and ponderosa pine growing in highly disturbed versus minimally disturbed areas (Geist, Hazard, and Seidel, unpublished manuscript in review). But a problem arises in that although compaction and other forms of soil resource damage are known to occur, it has traditionally been difficult to separate them into individual effects (Geist, Hazard, and Seidel 1989). However, monitoring information collected on the three Blue Mountain National Forests show compaction to be the most prevalent form of soil resource damage (Geist, Hazard, and Seidel 1989; Sullivan 1989).

Once soil productivity protection standards and thresholds were established, monitoring efforts were initiated to determine if those standards were in fact being met by our management activities. The first sampling systems devised were not statistically sound, could not provide repeatable results, and lead to general arguments of validity. This led the Pacific Northwest Research Station (in cooperation with Region 6) to develop a statistically sound sampling system (Hazard and Geist 1984), upon which most soil monitoring activities are now based. Guidelines for implementation of this procedure have been published by Region 6 (Howes, Hazard, and Geist 1983) and are in use in several Forest Service Regions.

In 1981, joint monitoring efforts were begun between the PNW Station, Region 6, and the Blue Mountain National Forests. The purpose of this effort was to evaluate impacts of forest management activities on soil resources and to determine if Regional soil protection standards were being met on harvest units that had been tractor logged and machine piled. On the Malheur National Forest, results showed that many of the sampled units exceeded standards (Sullivan, 1989). Eighteen of 27 units

(67 percent) exceeded soil productivity protection standards, and another 8 units (30 percent) were very near the standards, with 15 percent or more of their area being detrimentally impacted. Compaction was the primary detrimental soil condition measured, and it was shown that machine piling of slash and the cumulative impacts of multiple stand entries were the major contributors to excessive amounts of soil compaction. The Wallowa-Whitman and Umatilla National Forests also conducted monitoring efforts and obtained similar results (Howes 1985, Geist, Hazard, and Seidel 1989).

Stands which have had multiple entries are an indicator of those areas which may be experiencing reduced productivity and high levels of stress, and which may therefore pose a high risk for future insect and disease infestations. For example, on the Malheur National Forest it is estimated that 75 percent of the forested acres have had multiple entries in the past (Tim Sullivan, personal communication) while on the Wallowa-Whitman National Forest, the figure is estimated to be 49 percent (Woody Hauter, personal communication). Approximately 60 percent of the commercial forest land on the Umatilla National Forest has had multiple stand entries (Craig Buskohl, personal communication).

Dr. J.M. Geist at the PNW Station in La Grande, Oregon, has received reports of small areas of young trees that are apparently dying as the result of added stress of soil compaction. He intends to study the issue of stressed sites to further assess these and lesser problem areas. This research will be conducted jointly as a cooperative administrative study with the Blue Mountain National Forests and, eventually, other Eastside national forests. Early efforts will include investigation of more efficient monitoring methodology, assessment of the kinds and success of mechanical rehabilitation measures, and general assessment of the extent of management-imposed site stress. Later efforts will include testing the effectiveness of alternative rehabilitation measures (including vegetation rehabilitation) in restoring forest stand growth. Integral to the effort will be the development of stressed site indicators and a risk rating system to assist managers in evaluating present conditions and forecasting impacts of alternative management strategies. Expected cooperators also include the PNW Laboratories in Wenatchee and Bend and the Forest Engineering Department at Oregon State University. The Wallowa-Whitman National Forest has already committed support to the effort in fiscal year 1991.

Watersheds:

Although forest management can be used as a tool to enhance the quality of a watershed, some activities can eventually cause unacceptable changes in water quality, stream flow, and channel conditions. Increases in peak stream flows resulting from timber harvest may further degrade riparian areas already in poor condition as a result of extensive grazing, timber harvest, and other activities. Timing of flows may be altered to such an extent that irrigation use is adversely affected.

When watersheds are in poor condition, management options are limited until some degree of recovery occurs. The recovery of watersheds and timely conversion to healthy new stands of timber is impeded when remaining stands are weakened by insects or disease.

Watershed Condition:

The Forest Service uses watershed condition classes to provide an integrated expression of the health and basic trends of fundamental soil and water resources (FSM 2521). Watershed condition is a description of the health of a watershed (or a portion thereof) in terms of the status of hydrologic properties and soil productivity. Hydrologic properties include all characteristics of a watershed described in terms of its ability to sustain favorable conditions of water flow, including: Water quality, quantity, and streamflow regimen (timing of flows). Soil productivity is the inherent capacity of a soil to support growth of plants, plant communities, or a sequence of plant communities.

Watershed Condition is described by the following three classes:

Class I	-	Watershed condition is at or near potential.
Class II	-	Watershed condition is below potential but can be improved by applied management or other measures.
Class III	-	Watershed condition is at or below tolerance levels.

Potential refers to the inherent capability of a watershed to produce biomass and function hydrologically as determined by its physical, chemical, and biological factors. Tolerance level is the point beyond which there is a high risk that potential may be permanently impaired through changes brought about by management activities or natural events.

Based on the above definitions, it is estimated that 67 percent of the Malheur National Forest is in Class II watershed condition while another 1-5 percent is rated as Class III (Tim Sullivan, personal communication). On the Umatilla National Forest, 50 percent is rated as Class II while an additional 15 percent is rated Class III (Craig Buskohl, personal communications). On the Wallowa-Whitman National Forest these figures are 20 and 10 percent respectively (Woody Hauter, personal communication). These areas are either already hydrologically dysfunctional, or are likely to become dysfunctional. Weakened hydrologic systems are an indicator of increased stress and, therefore, an indicator of areas which may be vulnerable to insect and disease infestations.

An example of forest/watershed health interactions can be found on the Unity Ranger District of the Wallowa-Whitman National Forest. In the 1860's, the Whitney area had broad stands of old-growth ponderosa pine and wide riparian valleys. This has been altered by many subsequent activities; for instance, several miles of stream in the Camp Creek drainage were placer mined in the late 1800's and some minor placer mining continues today. This placer work changed channel morphology and gradient which, in turn, triggered downcutting and sediment movement that continues today. This was a major impact but other factors tend to exacerbate the problem: By the 1890's, a wide swath of land in the center of the valley was in private ownership. Between 1890 and 1940, nearly all ponderosa pine was logged off private lands, including many stands that shaded streams. Since 1930, the Forest Service has acquired most of this land and has replanted it to young stands of ponderosa pine. Since 1950, most of the old-growth stands in the uplands have been roaded and logged. Livestock grazing began during the late 1800's and continues today with significant streambank degradation in some areas. Streams have been diverted for irrigation purposes. As a result of all of this, the North Fork Burnt River in Whitney Valley has experienced severe channel downcutting and some of the sediment produced has been transported to Unity Reservoir.

Although the above example is only generally applicable to the lowlands of a given watershed, and though tree stands presently growing on the uplands of the three forests appear to be in generally healthy condition, analyses of cumulative watershed health have shown that negative impacts can occur on all parts of any given watershed. The indicators of watershed health are given below:

1. **Stream temperature:** Stream segments in the lower gradient alluvial valleys have high summer stream temperatures. This can be attributed to sub-optimal shade within 60-100 feet of streams, roads located too close to streams, harvested and mined sites that have not been revegetated, and riparian vegetation that has been grazed too heavily.

2. **Peak streamflow:** Scientific literature indicates that harvest of more than 22 percent of the volume in a forested watershed increases peak streamflow and advances the timing of the peak (Troendle, C.A. and C.L. Leaf. 1980). Even though each landtype in a watershed has a different threshold for for absorbing peak streamflow increases. To use the above example:

A model used by the Wallowa-Whitman National Forest indicates that watersheds in the Whitney Valley can be adversely affected by higher peak streamflows if streambank stability is not improved before more timber harvest and road building is scheduled.

3. **Streambank erosion:** Many stream segments in the alluvial valleys of the three Forests have significant streambank instability and sedimentation problems. One of the principal causes is overgrazing and trampling of streambanks by domestic livestock. Another cause is flooding which probably includes events as frequent as the 10-year return interval event. A third cause is believed to be increased annual peak streamflows resulting from timber harvest and road building activities in the upper watersheds.

Impacts on Downstream Values:

Events that occur in any given watershed may also influence downstream beneficial uses of water. These uses should be considered when planning management activities in upper watersheds. For example, we do not wish to produce water with high suspended sediment loads if downstream portions of the channel system are used as spawning areas by anadromous fish species, or if there are downstream irrigation diversions. Similarly, we do not wish to reduce storage capacity of reservoirs or detract from values of segments of rivers designated as wild and scenic.

Forest Health and Future Management

Land and Resource Management Plans for the three Blue Mountain National Forests emphasize water quality and quantity, maintenance of the productive potential of forest and range soils (including giving attention to compaction problems), and healthy riparian areas. In all three cases, the desired future conditions of the forests speak to maintaining or improving water quality, increasing anadromous fish production, and improving riparian area health. These improved conditions are to result from application of Forest-wide Standards and Guidelines and best management practices which apply to site specific areas as well as to whole watersheds, in all future management activities.

The Land and Resource Management Plan for the Wallowa-Whitman National Forest states the following:

> Give maintenance of soil productivity and stability priority over uses described or implied in all other management direction, standards, or guidelines. Exceptions may occur for such things as campgrounds or transportation facilities when it is determined, through environmental analysis, to be in the public interest (page 4-21).
>
> Give management and enhancement of water quality, protection of water courses and streamside management units, and fish habitat priority over uses described or implied in all other management standards and guidelines (page 4-22).

Forest Plans for the Malheur and Umatilla National Forests contain similar statements.

Given the above emphasis and direction regarding soil and water resources, what options are available to the Forest Service in dealing with large scale insect and disease infestations in the Blue Mountains? Also, how can the Forest Service help to prevent or minimize future infestations and improve overall forest health?

In dealing with large scale infestations, two options are available: The first option would be to manage within current standards and guidelines, while giving highest priority to protection of soil and water resources. This approach may limit the extent of stand treatment that could be proposed at any given time. The second option may be to deviate from standards and guidelines in the short-term in order to convert affected stands to a healthy, vigorous condition. In the long-term, this may turn out to be the best option for achieving healthy watersheds. Before these questions can be answered, however, detailed analyses of proposed actions and anticipated effects need to occur. A mix of both options may be the best strategy when viewed from a Forest or watershed perspective.

In order to further explore the relationships between watershed health and productivity, a conscious effort to achieve the following needs to occur:

1. Take an ecosystem approach to resource management. Plan and act with that view in mind. Look at whole watersheds, including downstream effects. Become more sensitive to cumulative watershed impacts.

2. Continue to monitor impacts of silvicultural and harvest systems on soil/water resources. Investigate relationships between these impacts and tree health, water quality, and riparian area condition.

3. Continue to support and cooperate with PNW Station research on stressed sites. Encourage them to study how stressed sites may relate to increased vulnerability to insect and disease infestations.

4. Prioritize sites for appropriate management actions based on results of above research.

5. Initiate measures to reduce site stress where appropriate.

WATERSHED MANAGEMENT AND FOREST HEALTH ISSUES

The Forest Health Assessment Core Team has identified a number of Issues which should be considered during discussions of forest health in the Blue Mountains (See Chapter I). The Issues which relate directly to watershed health and long-term site productivity are discussed below.

Issue 1 - **Planning**

Strict adherence to direction contained in Forest Land and Resource Management Plans will help meet the objectives recognized in this document. Hydrologic function of watersheds needs to be a prime consideration when planning all management activities. The necessary funds and personnel to fully implement Forest Plan provisions need to be provided. If objectives contained in Forest Plans for watershed health are met, we should go a long way toward achieving healthy stands of vigorous vegetation.

Alternative pathways for achieving desired results need to be explored. Long-term watershed health may be realized more quickly if short-term changes to Forest Plan Standards and Guidelines are acceptable. But before such a step is taken, more accurate watershed models need to be developed and validated. Forest Plan amendments, where applicable, should be considered.

Issue 2 - **Public Involvement**

The public needs to be made aware of the interrelationships between watershed health, hydrologic function, and the productivity of managed vegetation. Management activities such as timber harvest and road building may cause problems that increase vulnerability of vegetation to insect and disease infestations. In our haste to sanitize stands and salvage usable material, we may be perpetuating conditions which led to the problem initially. We may also be contributing to degradation of other resource values. If we are to take a long-term approach to forest management, we must also invite our publics to understand our management strategies. There is no short-term fix to the problem of declining forest health.

Issue 3 - **Resource Management**

We must be able to accurately state which activities and conditions in a watershed will affect the vulnerability of timber stands to insect and disease attack. At this time, we have an idea of what these activities and conditions are, but we do not have totally accurate means of describing the relationships and predicting future impacts. More research and monitoring is needed.

We must take a firm stand and not allow management activities that will adversely affect productivity of basic soil and water resources or the hydrologic function of forest watersheds.

Issue 5 - **Environmental Analysis**

Until we fully understand the vital interdependence of watersheds and forests, we should proceed with individual projects only after careful consideration of the probable effects our actions would bring. We need to be sure that our short-term actions do not, and will not, further degrade overall forest health.

A comprehensive watershed improvement program needs to be implemented if forest health objectives are to be achieved. Presently, appropriated funding for watershed improvement programs is minimal and/or fluctuates annually. This makes planning for multi-year projects difficult. Watersheds have not yet been classified as to their priority for treatment or treatment measures required. One problem is that a major source of watershed improvement funds is generated through Knutson-Vandenburg (K-V) collections. Work accomplished using K-V funds can only be done within active timber sales. This may preclude some high priority areas from treatment.

Issue 6 - **Pesticides**

Water quality is a major concern in the Blue Mountains. If pesticides are proposed as a treatment alternative, all possible measures must be taken to ensure that water quality is not degraded and that beneficial uses of water are not affected. Monitoring programs need to be designed and implemented in order to ensure that water quality objectives are achieved.

Issue 8 - **Forest Health Monitoring**

We need to continue to monitor the impacts of management activities on soil and water resources and further refine our prescriptions. A coordinated effort to validate our assumptions about effects of these impacts on the growth and vigor of vegetation is also needed. Relationships between vegetation growing on stressed sites and susceptibility to insect and disease attack must also be considered. Information provide by thorough monitoring will allow us to develop potential risk ratings.

Issue 9 - **Coordination**

We need to ensure that information gathered during our monitoring efforts is shared with adjacent landowners. The implications of our respective activities should be understood by all. Cooperation will help to give rise to a unified approach to implementing refined and improved management prescriptions. The impacts of activities occurring on other ownerships need to be included in our databases.

Issue 12 - **Long-term Site Productivity**

We need to avoid practices that create conditions which are known to reduce plant growth and vigor such as compaction, displacement, puddling, and erosion. We also need to plan our activities on a watershed basis and avoid activities or combinations of activities that adversely affect the hydrologic function of those watersheds.

Restoration of sites affected by past management activities should also be considered. In many cases, restoration may be the only management option available before additional activities can be implemented. Economic efficiency of restoration also needs to be explored.

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CHAPTER IV

THE ROLE OF FIRE IN THE BLUE MOUNTAINS

THE ROLE OF FIRE IN THE BLUE MOUNTAINS

Introduction

Fire is an important regulatory phenomenon in forest communities of the Blue Mountains, as it is in most areas of the intermountain western United States. Although most fire research has focused on other areas in this region, the causes and behavior of fire in the Blue Mountains are similar to what they are elsewhere in the West. Hall (1990) has synthesized research on fire ecology in the Blue Mountains and fire data that have been collected over many years. Ecological, physical, and paleontological evidence suggests that fires have been important for thousands of years (Hansen 1943, Arno 1980, Pyne 1982, Mehringer 1985), and very likely since the close of the Pleistocene (~15,000 years BP). The role of fire has been modified (excluded) since the turn of the century, resulting in a severe disruption of the natural fire cycle. Only in the past 20 years have we practiced more prescribed fire use in an attempt to offset the problems created by a fire-exclusion policy.

Tree ring data suggest that the average historic interval between fires in the ponderosa pine forests of Eastern Oregon was 13-18 years (Keen 1937). Since then, the frequency of fire has decreased but the intensity has increased. Changes in fire frequency in the Blue Mountains resemble changes in other parts of the West, e.g., in the southwestern United States, fire regimes in ponderosa pine forests have shifted from a 2-10 year interval between surface fires recorded at the turn of the century, to rare, stand-replacing fires in modern times (Swetnam *et al.* 1990). Evidence from these studies suggests that in pre-settlement times, climate and natural weather phenomena were the dominant force in determining the frequency of fires. The traditional extent and frequency of potential fires can be surmised from some historical data. In 1973, for instance, lightning ignited 220 fires in the Blue Mountains (Anon. 1973, in Hall 1976), or about 44 fires/million acres/year.

Early journals also provide information about fire occurrence in the western United States. Between 1833 and 1849, five large, extensive fires were reported to have occurred in the Blue Mountains (Gruell 1985). These fires were either in progress or took place within a year of the documented sitings. However, most recorded fires were found along major travel routes, so estimates from that time are probably low. In the first third of this century, about 750 fires were annually attributed to lightning storms over the national forests of Oregon and Washington. On August 1, 1929, a single storm ignited 87 fires in the Blue Mountains (Morris 1934).

Both "stand replacement" fires and low-intensity surface fires were common in the Blue Mountains. Stand replacement fires in the Blue Mountains generally give rise to a plant community that is dominated by lodgepole pine and larch; on the other hand, evidence shows that surface fires (which may be more difficult to detect) typically produce sites that are dominated by ponderosa pine. Generally, stand replacement fires do exactly that, and surface fires are stand-maintaining or stabilizing events. Historically, stand replacement fire frequency varied from 50 to 300 years in Blue Mountains grand fir communities (Hall 1990). The combined result of suppressing both these types of fires is a forest community that is different from one developed under a "natural-burn cycle."

The suppression of surface fires in the Blue Mountains has resulted in many changes in forests that were previously dominated by ponderosa pine. Perhaps no aspect of the Blue Mountains Forests has been so dramatically affected by fire suppression as the distribution of ponderosa pine. The mixed conifer/pinegrass ecosystem, which has arisen from fire suppression, occupies about 20% of the combined total acreage in the Blue Mountains (Hall 1976). Fire scars on ponderosa pine indicate that low-intensity surface fires have regularily occurred in the Blue Mountains for at least 300 years, with an average occurrence of at least once every 10 years (Hall 1976). Species such as grand fir were selectively eliminated by surface fires because of their heat-sensitive bark. Thus, surface fires produced very open stands, and served as a stocking regulator. However, because such fires have been suppressed, the forests of today have greater stagnation and greater components of fire-sensitive species and are therefore at greater risk to insect and disease-caused mortality and stand-replacing fire.

Tree growth is notably reduced when stands do not burn (Hall 1990); both tree height and diameter growth are affected by burning. Weaver (1947) advocated that fire should be used as a silvicultural tool in maintaining productive ponderosa pine forests. Morris and Mowat (1958) experimentally demonstrated the advantages of prescribed fire in ponderosa pine stands. Fire is advantageous to early seral species (in part) because Douglas-fir and grand fir have a competitive advantage when fire is removed from the ecosystems in which they are found. Because it is the most fire-resistant, ponderosa pine is the most likely to survive a fire. The true firs are the most susceptible to fire (Minore 1979).

Some early seral ponderosa pine/pinegrass communities have been succeeded by grand fir/ pinegrass communities due to fire suppression. Changes in understory shrub and forb composition are direct results of fire effects, and indirect results of increasing crown cover in stands that regenerate to Douglas-fir and grand fir. While site productivity, in terms of total wood-fiber production, may be as much as 20 percent greater when a stand is dominated by fir instead of pine, it is important to keep in mind that different silvicultural systems are needed for these types of communities. Differences inherent in the life histories of the species account for the differences in competitive ability. For example, the greater shade tolerance of both true firs and Douglas-fir make them easier to regenerate beneath a forest canopy. Therefore, selective cutting does not favor the regeneration of pines in any but the climax ponderosa pine communities.

Elimination of competition seems to be a key to regenerating ponderosa pine. For when competition is present, it may manifest itself in other kinds of vegetation (e.g. - grass or sedge mats in pine/ pinegrass communities). Some have suggested that inhibitory substances are found in pine litter, and when fire is not introduced these substances accumulate and reduce growth (or prevent germination) of pine seeds (Kelsey and Harrington 1979).

Another ramification of fire suppression is apparent in the overall change that is wrought on the species composition of forested rangelands. As forest canopies close to approximately 40% cover, less forage is produced. Furthermore, the species that are most palatable (such as pinegrass and elk sedge) decrease as the canopy closes. It should also be noted that the more nutritive forage species tend to flourish during post-fire succession, e.g., nitrogen-fixing species like *Lupinus* spp., and *Ceanothus* spp. which represent an important nutrient source. Thus in the absence of fire, the quality of forage is reduced (Hall 1990).

Another effect of fire is that species composition varies dramatically between areas that frequently burn and areas where fires are suppressed. In general, underburning promotes early-seral forbs, grasses, and shrubs; while, after an initial lag effect, stand replacement fires promote diversity -- mainly by structural and stand-age variation.

Fire-adapted species do not compete or regenerate well without the influence of fire. Certain species such as *Ceanothus* which as stated is a nitrogen fixing plant, require heat for germination. Other species, and particularly legumes (which are also nitrogen-fixing) like lupine and vetch, are also encouraged by fire. Lodgepole pine is a fire-adapted conifer throughout the Rocky Mountains and tends to do well in burned areas. However, the occurrence of non-serotinous cones on some lodgepole pine in the Blue Mountains often limits the role that these tree plays in post-fire composition.

Finally, stand replacement fires occur in areas where fuel loads are high and stands are multi-storied and dense. These fires dramatically alter the composition of the forest and the landscape, and tend to promote earlier seral stands. Perhaps the most threatening effect of fire suppression is the high fuel loading and vertical continuity of fuels that dramatically increase the risk of extensive stand-replacing fires. Fuel loads that under other conditions might have resulted in a surface-fire, now feed stand-replacing, conflagration events.

Silvicultural Ramifications

Wildfire is a governing factor in all vegetative aspects of the three Forests. Today, the unprecedented combination of decreased low-intensity surface fires, increased conflagration crown fires, and "fire-exclusion" management practices has resulted in the stand composition and structure that exist in the Blue Mountains. Those stands resulting from fire exclusion contain a higher percentage of true fir composition in the tree understories, resulting in mixed age structures and dense, suppressed tree stocking. Most stands not only owe their age and species composition to fire, but also their stocking levels. Fire intensity largely determines species composition, while fire frequency determines stand age (Hall 1990).

Low-intensity surface fires are capable of controlling tree vegetation, and recurring, low-intensity fires maintain stocking levels and perpetuate ponderosa pine, larch, and sometimes Douglas-fir. Crown fires, on the other hand, tend to create a stand of early-seral pioneer species such as larch and lodgepole pine. On either type of fire-affected site, without recurring, low-intensity surface fires, an overstocked stand can develop and may eventually evolve into a stagnated conifer stand of mixed sizes and species.

Fire behavior is an important consideration in determining management consequences. If our long-term goal is to perpetuate stands of ponderosa pine, the judicious use of fire seems to be warranted (Arno 1984). In other words, to achieve a fairly open, managed stand of early-seral trees, the repeated use of prescribed low-intensity underburns may be appropriate. Conversion of a fir site to early-seral pioneer species requires a prescribed, stand-replacing burn similar in intensity to a crown fire. On the other hand, if a multi-storied, mixed-species stand is the objective, as much fire exclusion as possible is warranted.

In some instances, the result of fire suppression is an uneven-aged forest of trees that grow in even-aged groups (Cooper 1960); in others, the result is a forest of distinct, uneven-aged groups that are derived from individual tree replacement events (White 1985). A type of gap-phase regeneration has been suggested in the Blue Mountains (Hall 1990), wherein a group of five trees must be established once every 35 years to achieve a stand of 50 ponderosa pine per-acre. Weaver (1967) explained the regeneration mechanism, and White (1985) reported on similar regeneration cycles in Southwestern pines: Woody material, (perhaps only one tree) may burn to mineral soil, exposing a seed bed for ponderosa pine, while also eliminating competing vegetation. Additionally, the fuel load is reduced, so regenerating seedlings are spared from fire for the first few years.

A scenario based on fire interval has been developed for some grand fir plant associations in the Blue Mountains. Communities pertaining to the grand fir/pinegrass plant association exhibit open stands dominated by ponderosa pine and larch when fire frequency is approximately every 10 years. The likelihood of a stand-replacing fire is rather low because of the light fuel loadings and lack of vertical fuel continuity (fuel ladder). These pine and larch stands are converted to Douglas-fir and/or grand fir as succession advances. Only in the cooler, moister plant associations can larch and lodgepole pine maintain dominance in long-interval fire regimes. Grand fir/twin flower plant communities are initially dominated by lodgepole pine and/or western larch stands following stand replacement burns (Johnson and Simon 1987).

Increased production of multi-layered canopies is a direct result of fire suppression. This phenomenon fosters defoliating insects, stem decay, and dwarf mistletoe problems. Additionally, the increase in host species, particularly the shade-tolerant conifers, has contributed to the insect infestations and disease impacts that plague the three-Forest area. The decrease in fire in many areas of the western United States relates positively with the duration and intensity of attacks of: Western spruce budworm (Anderson *et al.* 1987, Carlson *et al.* 1983), Douglas-fir tussock moth (Brookes *et al.* 1978 and William *et al.* 1980, among others), mountain pine beetle (Mitchell and Martin 1980), dwarf mistletoe, and root diseases (Byler 1984).

Mild or moderately hot fires are advantageous because of the nutrient recycling capability they provide. Low-intensity fires can stimulate short-term plant growth, but really don't contribute to soil fertility. Fires accelerate release of nutrients held in the litter or vegetation that would have been released more slowly through mineralization, but some losses of nitrogen or sulfur may occur through volatilization at extremely high temperatures (Stark 1987). Therefore, conflagration fires that burn an unusually high fuel load may actually decrease soil fertility on a given site for many years.

After decades of observing the effects of fire suppression, we've reached a better understanding of the importance of fire in maintaining ecosystem processes in the Blue Mountains. Healthy, productive forests may arise from the wise use of fire. However, given the current conditions *vis-a-vis* high fuel loading and the multi-storied stand structure of the Blue Mountains forests, a return to a "natural burn cycle" would be difficult.

The Role of Fire in Maintaining Forest Health

Fire has been a regular, periodic, and naturally occurring event in the plant communities on lands administered by the Malheur, Umatilla, and Wallowa-Whitman National Forests. Endemic levels and occasional epidemics of forest pests (insects and diseases) are also a natural part of the forest ecosystem. The more recently observed high incidence of epidemic insect and disease outbreaks and the damage they incur result from drought, damaging harvest practices, and withholding fire from the ecosystem.

Historic Background

Human-caused fires usually result from purposeful or careless acts. Native Americans and early settlers used fire to improve grazing conditions and to flush game resulting in the first use of fire employed by humans to modify vegetation.

The most noticeable modifications of vegetation in the Blue Mountains National Forests were the results of naturally occurring fire. The periodicity of fire varies, depending on environmental factors which influence the vegetation potential and the ability of that vegetation to carry fire. Therefore, some plant communities are more frequently visited by fire and are adapted to this greater frequency. Other plant communities are infrequently visited by fire and often have a greater vulnerability to its effects.

Examination of fire scar information provides a record of ground fires (Hall 1976). In the southern Blue Mountains, where fires have created open, park-like stands of older ponderosa pine, fire frequency has averaged one in every 10-15 years. Vegetation has adapted to these surface fires because it is capable of resprouting in moderate-intensity burn areas.

In the Snake River canyon, elevations range from 1,000 to 9,000 feet. Vegetation there varies from bunchgrass steppe to subalpine forest. Between 1986 and 1989, a 20,000 acre fire burned in the 84,000 acres administered by the Wallowa-Whitman National Forest in Hells Canyon NRA on the Idaho side of the canyon (Lukens 1990). If this fire was representative of what we call a natural fire regime, and if natural controls only are assumed, we could expect that wildfire will periodically visit a site such as this every 15 years. Another observation by Lukens is based on 20-year fire records that are kept for the North Fire Zone of the Wallowa-Whitman National Forest. His records show ignitions-per-season and fire dispersion across the Zone. Based on these records, fire can be expected to visit this area every 15-30 years.

The drier the climate, the more xeric (hot, dry adapted) the vegetation, and the greater the incidence of fire. For example, some ponderosa pine plant associations have adapted to a fire frequency of one every 10 years or less. But at the mesic (cold, moist extreme), grand fir plant associations have adapted to a fire frequency of one every 50-300 years (Hall 1990).

The topography of the Blue and Wallowa Mountains provides for a wide variation in plant associations due to having a range of relief, latitude, and prevailing climatic patterns. Principal plant associations, when grouped into series, reflect the land's potential to support bunchgrasses, shrublands, ponderosa pine, Douglas-fir, grand fir, subalpine fir, and whitebark pine. This listing is progressive -- from dry, warm environments where grasslands dominate the landscape, to cold, moist environments where sub-alpine communities dominate. Fire tends to be more frequent in the bunchgrasses, which therefore exhibit greater resilience. Due to higher humidities and cooler summertime temperatures, fire at the higher elevations is less frequent. When fire does occur in such a setting it usually has little impact or, but if fire burns into the crowns of trees, it can cause stand replacement.

The historic patterns created by underburning promoted the ponderosa pine dominance that formerly characterized this region. Fire also promoted shrublands in the forest plant communities. Grasslands were stimulated by its frequency, and mule dear responded to this promotion. With fire as a regular force in the ecosystem, biological diversity was high. The landscape was rich with older, seed-bearing trees that were sufficient to propagate and maintain ponderosa pine dominance. This is no longer the case because the primacy of the role fire played in maintaining forest health has been superseded.

Creation of The Current Situation

Over the years we have invested money, human energy, and cultural work in the forested stands we managed. Fire has been viewed as a threat to these investments. Although we have been fairly successful in stopping fire and lessening its impact on forest vegetation, the forests themselves have evolved in directions we did not anticipate. This evolution has been mostly responsible for creating the pest problems and the high-intensity fires that have visited the Blue Mountains National Forests in the recent past.

The ponderosa pine forests that became so predominant in the Blue Mountains, were the result of periodic underburning. Fire events were frequent enough to reduce the successional tendency of grand fir and/or Douglas-fir to dominate over ponderosa pine. The role of the underburns was to maintain grand fir plant associations in early-seral stages where pine was the dominant tree in overstories as well as understories. Fire's ability to promote pine and exclude its competitors can best be illustrated by an example:

> After an underburning event, openings are created where mineral soil is exposed, enabling ponderosa pine seedlings to readily establish in spots where competition is lessened. Here, sunlight is plentiful and growth is rapid. During the first five years, the healthier tree seedlings dominate the grasses and sedges. In this timespan, though, they are also susceptible to ground fire that may result in mortality.

As the clumps of young seedlings emerge and cast needles, their susceptibility to ground fire increases. Any subsequent fire event will serve to thin some of the clumps of young trees. At this stage, because the fuel buildup is relatively low, fire tends to be of a lower intensity, and some of the more vigorous trees withstand the heat, though the thin-barked, less vigorous saplings are killed.

As the pine trees continue to grow, the risk of fire mortality continues -- because the stems are practically even-sized and the "ladder fuels" beneath them are capable of lifting fire into their crowns. When the trees reach an intermediate size and have been thinned by fire to the point where they are more separated, fire is less likely to kill trees.

And finally, by the time they are older, pines develop a thick bark that protects them from ground fires. The needles and lower branches drop, effectively eliminating ladder fuels that would allow fires to reach their canopy. And this litter serves as a fuel bed upon which fire reduces competition with the understory firs.

Problems presented by the absence of fire have been compounded by some harvest practices that are not in the best interests of forest health. The selective-harvest strategy that was followed until the early '70's furnished ponderosa pine dominants to a sawlog industry that was built to produce pine lumber products. In the 1970's silvicultural operations were intensified to bring stocking levels under control. This was done through harvesting slow growing trees and promoting the faster-growing, fiber-producing tree species. As a result of this process, pine dominants were removed from large areas, pre-commercial and commercial thinning operations were used to reduce tree understory densities, and fir was promoted. This promotion was successful, not only from a silvicultural standpoint, but also because fir responded well to a management practice that eliminated fire from the ecosystem.

However, not all acreages could be silviculturally treated. Thinnings lagged behind or were not scheduled on poorer growth sites. As a result, the ingrowth of fir was rampant and widespread. Insects that normally occur as part of the natural processes of tree and stand mortality were able to increase in stagnant stands where tree vigor had depreciated. Moreover, insects that prefer Douglas-fir and true firs were able to proliferate in areas where the slow-growing seedlings, saplings, and pole-sized trees were becoming available. But most importantly fire, in it's normal, cleansing role, wasn't present in sufficient frequency or intensity to control the infestations. Drought in the '80s only provided a boost to the growing populations of insect pests. Therefore, perhaps the most fundamental causal agent for the "epidemic" insect problems we now face was the exclusion of fire from its role as a discriminating force against fir succession under pine-dominated stands.

The role of fire exclusion in the present outbreak of insects and diseases is wider than even that, however, since the insect and disease epidemic is not confined to those stands where the absence of fire has enabled true fir to succeed under early seral pine-dominated plant communities. The higher elevation and more mesic (cool, moist adapted) true fire plant associations are also affected, because fire has historically modified communities in these plant associations as well. The higher elevations may have sometimes been spared stand replacement by fire when humidity and/or ground moisture conditions limited fire to underburning, or topographic isolation of stands left stand segments unburned, but the common role of fire in true fir dominated communities has been to replace the stands in a renovating activity. Historically, replacement fires have not engulfed expansive acreages in the tri-Forest area due to firebreaking provided by the varied topography and associated vegetation discontinuities. These replacement burns provided structural diversity to the landscape when early seral tree and shrub species pioneered the sites prior to the return of fir dominance, and the species diversity was often improved by the introduction of western larch, lodgepole pine, Douglas-fir and ponderosa pine (depending on the plant association).

Effects of Fire

Fire promotes fire-resistant species and discriminates against fire-susceptible species. It helps build landscape and species diversity; by helping to remove dead, diseased, and weakened individuals, it rejuvenates forested communities. The creation and maintenance of pine-dominated stands has been important from a sanitary, tree-stocking standpoint. Fire has promoted and supported wildlife and plant species that are better adapted to areas of open, early-seral vegetation and stand structures. Periodic fire consumed lighter, "flashy" fuels and thereby, burned cooler. When fire was removed from the system, fuel loadings increased. Then, when fires occurred, even these nutrient reservoirs (large woody material) were consumed rather than recycled. Fire's ability to discriminate and reinvigorate is lost when stand conditions provide the fuels and fuel ladders that will take fire from the understory to the crowns. A direct consequence of total fire exclusion and the loss of fire's periodic maintenance functions in forest communities is the increased risk of extensive stand-replacing fires. The incidence of larger fires with consequently greater tree mortality is more likely now than it has been in the past. This increase in frequency and intensity is not only the result of natural fuel accumulations, but also of the increased tree mortality that results from insect infestations and diseases.

Stand-replacement fires are not necessarily bad. If timber protection is the management objective, prescribed underburning or surface fire is the desired kind of fire activity. If forest health is the objective, stand-replacement fire could be sponsored to promote a diverse mosaic -- of species composition, age classes, and seral stages. Therefore, stand replacement fire activity could be promoted to help provide desirable patterns, and silvicultural activities could aid in providing these patterns. The Ryder Creek Fire of 1987 is an example of how a large fire can serve to enhance landscape diversity. Vegetation on the predominantly south-facing slope was composed of pine-dominated stands, mixed-conifer stands, and true fir-dominated plant communities. Surface fire was the primary activity throughout that fire event. Periodically, the fire would rise with atmospheric conditions to consume an entire patch of vegetation, and the intensity of the crowning fire would leave a stringer, or island, with total mortality of tree and undergrowth. The haphazard movement of this fire provided new seedbeds, natural seed sources, and increased variation of tree structure and age groupings. Shrublands and grasslands were also enhanced.

Fire, Smoke, and Insect Relationships

Although fire alone can serve to control stocking levels, eliminate or reduce understory tree species that promote insect outbreaks, and help restore biological diversity, some data suggest that smoke from wildfire or prescribed burns may also affect insect and dwarf mistletoe activity in wildland plant communities (Parmeter et. al. 1974., Frandsen 1982). Prior to the implementation of present-day forest management projects that include fire exclusion, fires were frequent and smoke was a normal feature of the environment (Biswell 1972). And, of course, the preservative and antimicrobial effects of smoke have been known for thousands of years.

Surfaces exposed to smoke have been found to be unsuitable for the germination of spores of several kinds of fungi, some of which are common to forest environment, e.g., *Peridermium harknessii* (a gall-forming rust of pines), *Fusarium lateritium* (a stem pathogen of forest trees), and *Fomes annosus* (a forest tree root pathogen) (Parmeter et al. 1974). Mycelial growth itself also declines as exposure to smoke increases. This occurs with *F. annosus* and *Verticicladiella wagenerii* (two forest tree root disease fungi); *Trichosporium symbioticum* (a bark beetle symbiont); and *Pholiota adiposa* (a heart rot fungus). Zimmerman & Laven (1987) noted that smoke exposure reduced germination of dwarf mistletoe seeds in their study. In another study, reductions in the number of galls were observed on Monterey Pine trees that were smoked for at least four minutes, and no galls appeared on 34 trees smoked for larger than four minutes prior to inoculation (Parmeter et al. 1974).

Certain insects that spend part of their life cycle in the duff or down woody debris can be reduced by fire if they are either on the ground when fire occurs or if fire reduces suitable habitat. To date, the use of fire and/or smoke to control forest insects and pathogens has not been conclusively proven to be an effective treatment, nor has it been shown to be practical. However, the data and observations that have been documented lead to the recognition of many unfulfilled possibilities in the way of using fire to suppress insects and diseases. Additional data is needed.

Reintroduction of Fire

Fire can be reintroduced to the ecosystem by permitting prescribed natural ignitions to burn, controlling extent and intensity of natural ignitions, and through the use of prescribed management-ignited fires in specific areas at specific times and controlling the intensity of the burn. The use of prescribed natural fire may result in higher intensity burns with some concurrent stand replacement. Management-ignited fire will perform more characteristically as an underburn, a partial-replacement, or full-stand-replacement activity, depending upon what is desired. The reintroduction of fire could help to stimulate fire-resistant plant species, selectively thin stands, reduce fuel loadings, and reduce the risk of large, extensive, stand-replacement fires. Some of the benefits of such activity would be: An increase in biological diversity; improved vigor and vitality of plants and plant communities; and increases in the early- and mid-seral plant species. However, some short-term and possibly some long-term detrimental effects on wildlife and fisheries may occur, such as the loss of hiding cover and degradation of water resources. Cool underburns could lessen or eliminate the negative effects over the long run. Some positive effects would be marked improvement in the availability and palatability of forage and browse species, promotion of nutrient recycling, maintenance of some large woody material for improvement of long-term site productivity, and the removal of understory tree clumps that are havens for insect activity.

If fire is to be effective, it must occur on such a scale and at a such a frequency that tree species hosting forest pests are effectively reduced. Effective use of fire would probably entail annual unit-treatment operations over several thousand acres, rather than the few hundred-acre units that are currently treated. Silvicultural activities can effectively serve to enhance fire treatment. Simultaneous planning and implementation of silvicultural/fire-management operations would serve to improve tree vigor and species composition and avoid the catastrophic effects of insects and disease.

The encouragement of more "regular" fire discourages the faster growth and fiber production of fir species. However, if we consider diversity to be one of our management goals, we should ensure that fir species are a component of some pine-dominated communities, as well as those communities in the the mesic fir associations. Silvicultural thinning in conjunction with more natural fire patterns on the landscape will enrich the species mix, and both stand and landscape diversity will be increased. Increased fire activity may favor pine, larch, and Douglas-fir over grand fir and subalpine fir, but these late-seral species are also important components of a diverse forest ecosystem.

Stand-replacement fires are a feature of healthy forests. The size, intensity, and duration of such events are primary to this discussion. If a fire is large but exhibits discontinuous stand replacement across the area burned, the species, stand, and landscape diversity should improve, and overall forest health should likewise improve. A more continuous stand-replacement fire that occurs over a larger acreage is less desirable from a commodity-production standpoint and will improve landscape diversity to a lesser degree. The need for stand replacing fires becomes more apparent as large areas accumulate fuels that result from the mortality caused by pest infestations.

We recognize that to burn all fuels in all affected areas is not desirable. Even in severely infested communities, fire should be managed to promote diverse habitat, maintain stand structure and variation, and retain enough large woody debris to maintain habitat and site productivity. Fundamentally, the role of a stand-replacing fire is to support the creation of new seedbeds, shrubfields, grasslands, and open spaces; and to diversify the age-structure groups across the landscape and provide a varied vegetation mosaic. Using silvicultural treatments (e.g., clearcuts, shelterwoods, seed tree cuts) in conjunction with fire will also create the desired openings.

Long-Term and Short-Term Consequences

There is no doubt that it is a short-term risk to return fire to ecosystems from which it has been long absent, particularly in true fir plant associations where fuel conditions (loading and vertical continuity) are especially severe. In these communities, the immediate effect of stand replacing fire may be resource damage: Consumption of down woody material with subsequent nutrient loss; the degradation of water and air quality; wildlife cover loss and animal displacement; and reductions in soil seed bank and fertility. Conversely, the long-term consequences of high-intensity, stand-replacement fire are, more beneficial: Recovery of wildlife habitat; recruitment of animals into the burned area; the creation of vigorous shrublands and younger patches of trees, and the overall improvement of landscape diversity. Once fire becomes part of a recurrent cycle, maintenance of the health, vigor and vitality of all members of the plant community (flora and fauna) are promoted.

In more open forest stands where pine, Douglas-fir and grand fir coexist, fuel buildup has been less heavy (though still abnormally high). Therefore, stand-replacing fires may have less severe impacts on the associated resources of soil, water, and wildlife. Although it should bring about the stimulation of rhizomatous shrubs, sedges, and grasses, which may improve the abundance, palatability, and nutrition of forage and browse. With cover decline and shrub increase, wildlife species shifts can be expected to occur. Early-seral and fire-tolerant species should proliferate, exhibiting greater utility for non-game wildlife and a wider spectrum of wildlife species. Nitrogen-fixing plants should also become more prominent and provide a valuable contribution to rebuilding the nutrient base. In addition aspen clones, once more prominent and vital in the Blue and Wallowa Mountains, are enhanced through periodic burning, so they should increase as well.

Social Consequences to Active Fire Employment

Public response to the Yellowstone Fires of 1988 provided land managers with an interesting vantage on the magnitude and duration of catastrophic events, especially with respect to the modification of vegetation along the visual corridors and the high cost to contain and suppress the fires. Although these fires were large, they provided a long-overdue rejuvenation to the lodgepole pine-dominated communities. In general, the burned portions of Yellowstone National Park now contain healthier vegetation than they did before the fires. The most recent public opinion seems a favorable view on the succeeding vegetation and on the efforts by the National Park Service to interpret the changes wrought by the wildfires.

A similar public response has been generated as a result of the large fires of the past five summers in Northeast Oregon. The reintroduction of fire as a regularly occurring event that promotes forest health can be a proactive part of our public outreach program. Fundamental ecologic principles can be taught at primary and secondary schools, at county fairs, on radio and television, and in the printed media. Forest Service officers spent many years convincing the public that fires were an enemy of the forest. We adopted a symbol of that effort that has become synonymous with our organization. Now our challenge is to reverse the perception of that role and employ fire as a tool to regain the healthy forest landscape it once provided.

The consequences of increasing the use of fire in northeastern Oregon and southeastern Washington may be controversial. For example, it is likely that the commodity users will consider the losses to be too great in the short run. With fire as the preferred treatment in rejuvenating stands and the shifts to uneven-aged strategies, the retention of disease and insect riddled trees may elicit concern from the local economic organizations. In addition, particulates produced by fires will be of concern in the more urbanized communities located in the intermountain valleys of the region.

On the other hand, if fire is not employed we are likely to see a continuing deterioration in the quality of the forests with an associated heightened risk to catastrophic loss by wildfire. Therefore, the programmed use of fire and silviculture to enhance the forest landscape through creation of multi-aged patches should reduce the size and degree of commodity loss from future wildfires, an effect which should be of economic benefit in the long-term. The programmed use of fire and silviculture may be viewed skeptically in the short-term by some users. For example, recreationists may find that the quality of the Forest landscapes may decline with application of fire and harvest practices. However, the long-term prognosis would be a more pleasing landscape, which provides a full range of opportunities.

Visitors to the National Forests can be brought to recognize that blackened trees are a rejuvenating factor that will ensure future green canopies and a multitude of other natural resources. The success of management change is crucially tied to developing an interpretive campaign for the public. Our new message is that healthy forests are created and maintained by periodic fire in Northeast Oregon and Southeast Washington; it has been that way for millenia.

THE ROLE OF FIRE AND FOREST HEALTH ISSUES

Issue 1 - **Planning**

As we shift from project-level and stand-level planning to an approach that more thoroughly considers ecosystems and processes, we are recognizing a need to use fire as a means of providing natural diversity and, by its reintroduction, change forest plant composition to a more vigorous mix of early seral species having greater resistance to forest insects and diseases. To provide healthier forests we will need to promote the combined use of fire and silvicultural treatment methods. The desired direction of our management activities is to participate in processes which allow mosaics of vegetation to create, promote, and maintain biodiversity and long-term site productivity.

In order to plan for this goal, it is necessary that we understand inherent site characteristics, and the relationships between plant communities and their associated wildlife. An understanding of how these communities relate to disturbance, as well as how disturbance can enhance biodiversity and overall forest health, is fundamental to any plan that strives to address and encourage ecosystem vitality. The functional needs of planning teams may entail resource specialists who work with the sets of values found in multi-seral vegetation mosaics and their associated plant and animal communities. The scale and timeframes associated with projecting the development of entire areas as they go through their natural cycles require constant scrutiny. The cycles that planners should seek to emulate represent the average periodicity of the rejuvenating disturbances that are found in nature. Land and resource planning should relate to whole processes, and part of the planning cycle should include the modification of project activities where appropriate.

Plans that are developed may call for greater encouragement of some natural ignitions, the promotion of prescribed underburns, stand-replacement burning, and clearcutting followed by burning. Of course, these plans will be subject to change when natural fire modifies the planned mosaic. Fire may be used to reintroduce a regularly occurring event in those plant communities composed of plant associations that have adapted to sites with a high incidence of fire. Such prescribed ignitions should be conducted during times when the extent and intensity needed to achieve Desired Future Conditions can most easily be attained. Implementation teams that include seasonal and full-time persons who are skilled in fire management techniques will be necessary to achieve fire management goals.

Issue 2 - **Public Involvement**

A certain level of public concern can be expected if fire is regularly used to manage the national forests. Community outreach and education will be necessary to promote an understanding of the value of and the need for fire in forest management.

The Yellowstone National Park fires of 1988 provided a clear example of misunderstanding the formative and rehabilitative role of fire in the creation of the Yellowstone forest landscape. Our job will be to inform the public that fires are not the "enemy," but the ecological "friend" of a healthy, vital forested ecosystem.

Information is the key to changing our image from one of protectionism and exploitation to one of "stewardship." The information that we provide our publics can serve to foster a better understanding of the role of fire in maintaining ecosystems that support life, and provide our amenities and necessities both. The vision that we share with our public partners can include an understanding of the importance of blackened trees as well as green canopies. The mixed nature of the visual landscape, with patches of early seral vegetation, openings, and brushfields, as well as stately older trees as part of the mosaic, can be understood as a more natural landscape than are homogeneous green expanses. The late Summer and Fall traveler can be encouraged to understand that particulates in the air are as natural to our mountains as the vegetation which cloaks them. Interpretive signing will be an important means of conveying messages that tell of the ecological role of fire in the Blue Mountains.

Issue 3 - **Resource Management**

The current insect and disease situation has, fundamentally, been created by the removal of fire from its role as stand rejuvenator, stocking level controller, and species discriminator. Additionally, the harvesting of large overstory trees, the particular preference that we've had for ponderosa pine, and the promotion of faster-growing fir (with subsequent cultural work), has diminished the stands' ability to weather epidemic outbreaks. The reintroduction of fire at a scale and frequency that can help curtail infestations of forest pests is desirable. By using silvicultural stand- and tree-improvement practices, as well as underburning techniques, we may be able to invigorate many of the Blue Mountain stands that we manage. And though it is true that the use of stand-replacement fire and the (probable) loss of standing crop trees would diminish the availability of commercial timber on some areas of the Forests, the improved tree vigor promoted by the use of fire and silvicultural activities would help diminish the future risk of insect and disease epidemics.

As a result of epidemic insect and disease infestations, wildfires, and unrecognized losses, sustainable timber yields estimated in Forest Plans may be overestimated. The Forests' Allowable Sale Quantities (ASQ's) for the short term should reflect incursions that have been made by the pests. They should also reflect the necessary changes in available harvest acreage that will result from an increased use of fire. The inventory upon which timber production estimates were based when Forest Plans were developed used calculations that projected growth on potential crop trees. Since the inventories were conducted, much of the timber volume that was measured has suffered mortality or experienced reduced growth. More may be lost to cultural practices that are used to promote biodiversity.

The stimulation of shrubs, forbs, sedges, and grasses resulting from burning should, for the most part, improve wildlife habitat. The greater diversity provided by this process will increase the abundance of species and increase populations of browsing mammals. Higher deer populations may result, along with a reduction in cover for elk. As we shift from stand emphasis to ecosystem emphasis in our management, wildlife should benefit from the greater variety of habitat.

Riparian vegetation can be damaged when non-sprouting shrubs are consumed by fire. However, many riparian areas are capable of repelling fires. The ratio of burned-to-unburned parcels of riparian communities following wildfire should provide healthier conditions than exist under the current regime of fire exclusion and resource protection. Prescribed fire can be used to help achieve riparian management objectives.

Old-growth allocations are vulnerable to fire-induced modification and loss. It will be important to include future old-growth units in planning for healthy forests. In mesic fir forests, fire may replace preserved old growth. In xeric fir forests, where fire has promoted the late-seral ponderosa pine, old-growth characterization will require that underburning be continued to help preserve the older pine trees.

Issue 4 - **Pest Prevention and Suppression**

The uses of fire and silvicultural practices are the most natural and easiest ways to decrease the incidence of pest outbreaks and, ultimately, to keeping them within endemic levels. Research should be promoted to determine the degree to which natural insect predation by native fauna can be encouraged through the maintenance of suitable habitat. Secondary cavity nesters may be better able to regulate insect populations if older overstory trees and snags are retained on-site. They will not be able to avert pest outbreaks, however. Pesticides use should be viewed as a short-term, stop-gap measure, and not as a permanent or long-term "fix."

Issue 5- **Environmental Analysis**

Any project-level analysis will be conducted in compliance with the Final EIS for Managing Competing and Unwanted Vegetation and its accompanying "Mediated Agreement," as well as within the strictures of any other programmatic environmental documents that are applicable to the proposed activities.

Issue 6 - **Pesticides**

Pesticides should only be used when any other viable treatment methods would not be effective or when those treatments' costs would be unreasonable.

Issue 7 - **Pest Suppression Technology**

In order to efficiently and effectively protect the forest resources from insect and disease damage, reintroduce periodic fire for maintenance of more natural forest species compositions; practice precommercial thinnings to promote vigor; and discriminate against susceptible fir species on poorer sites. The combined use of these practices will enhance even-aged management, and uneven-aged management practiced in appropriate plant communities, and will stimulate diversity across the landscape for greater protection from insect and disease epidemics. We need to disseminate information that will help to develop an understanding that some level of insects and diseases are essential to an ecologically sound forest, and that fire is important to maintaining those levels.

As we manage resources for healthier forests we will be leaving pest-riddled trees, stands, and landscape fragments behind. We need to undertake a proactive campaign to share our understanding of forest health, and provide examples of how we manage ecosystems. Our practices for intensifying timber harvest have been employed for a century on the national forests. It will take just as long to see effective changes resulting from ecosytem management practices.

Issue 8 - **Forest Health Monitoring**

We do not know all we should to practice ecosystem management. We will make mistakes, and we will learn from them. As we employ fire to create, enhance, and modify the landscape, it will be necessary to actively and regularly monitor our lands. Monitoring our activities immediately before and immediately after we do them is relatively easy. It will be those monitoring activities that must be conducted long after the implementing manager has left that will require our greatest professional sensitivity. We are embarking on a management approach which will transcend our lifetimes. It will therefore be crucial that we have a deep resolve as an organization to plan for futures which we as individuals will not know, but which will carry the effects of our stewardship to the generations that follow.

Monitoring activities would involve sampling before stand modifying activities, post-activity sampling, data storage for planned future monitoring. Districts would provide interdisciplinary teams to interpret results, redirect the flow of activities, and document the findings for future ecosystem managers.

Issue 9 - **Coordination**

The National Forests are like islands surrounded by forests and rangelands which are owned and/or administered by State, private, and other Federal groups. We can improve our forestlands by actively using fire and silviculture, and by choosing to limit those activities in other portions of the landscape. The practices of fire exclusion and fire inclusion to promote certain diversity and insect- and disease-oriented objectives could be jeopardized by adjacent landowner's practices. Therefore, it will be important that we work with the State, Private, and other Federal sectors to help promote the changes we will be making. We will need to coordinate with, among others, State extension foresters, small woodlot organizations, BLM, SCS, and Native Americans.

Issue 10 - **The Role of Fire**

We reintroduce fire and its historic role in modifying and rejuvenating our national forest lands by making a fundamental organizational shift from tree and stand management to ecosystem management; by reducing the emphasis on commodity extraction; and by initiating a campaign to inform and involve the public regarding the natural role of fire as an element of "protection" for the forest.

Issue 11 - **Biodiversity**

Natural fire was instrumental in the formation of the forests of northeastern Oregon and southeastern Washington. By its very nature, it is haphazard in extent and in intensity. It therefore provides natural diversity by its periodic occurrence and its seemingly random behavior. We must provide enough scientific information (in demonstrating the application of fire) so that our protectionist past is replaced with an attitude that fosters a public trust of the approaches we will take to ensure diversity. There needs to be a recognition at all levels that diversity enhancing projects are not conducted incidentally to commodity extraction.

Issue 12 - **Long-Term Productivity**

Enhancement of long-term productivity results from a "light-on-the-land" approach to management. Less frequent visits into project areas will be necessary (especially where heavy equipment has been used), and leaving biomass behind to decompose will add to the nutrient bank. Intense fire may be detrimental to long-term productivity, because it will consume important sources of down woody material. However, in the long run fire will facilitate nutrient recycling, the recruitment of larger-dimension trees for future down woody material, and the management of an ecosystem which depends on fire (instead of extraction activities) to promote diversity objectives. Thus, the use of fire will decrease the use of heavy ground-compacting equipment.

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CHAPTER V

LONG-TERM PRODUCTIVITY

MAINTAINING THE LONG-TERM PRODUCTIVITY OF BLUE MOUNTAIN FOREST ECOSYSTEMS

Introduction

Long-term productivity literature indicates nutrient capital cycling and biological and genetic diversity are most important factors in ecosystem integrity and resiliency. Resilience is the ability of the 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 by managing for biological diversity; that is, diversity of species, diversity of successional stages in both space and time, and diversity in the size, shape, and distribution of openings across the landscape. Retaining the structural elements of ecosystems associated with both species and landscape diversity will, in turn, preserve the functional relationships of ecosystems that lead to resilience in the first place.

We are a long way from full understanding of the resilience of forest ecosystems. But we do know that the central factor to that understanding is the awareness that land managers may have an affect on the subsequent conditions of the forest and an impact on the future productivity of forest lands. This realization has prompted new attempts to examine the maintenance of productivity (Miller et al., 1989). While much remains to be understood of the attributes of productivity in temperate forests, even less is known about interior forests of the Pacific, and data on the Blue Mountains are particularly scarce.

Land managers and administrators of the Blue Mountain National Forests have a fundamental goal to maintain the long-term productivity of the land. Managers on National Forests in general are directed to protect the productive potential of the forest by the Multiple-Use Sustained Yield Act of 1960, the National Forest Management Act of 1976, the Forest Land Policy and Management Act of 1976, and the National Forest Environmental Protection Act of 1969. In addition to these laws, the Forest Service has also adopted self-regulatory Standards and Guidelines to ensure that a sustainable multiple-resource base will be maintained. How resources are used or misused is ultimately decided by the resource manager who implements site-specific projects and makes on-the-ground decisions.

The ability to meet long-term production goals is contingent on the capability of the land to support ecosystems that produce forage, timber, wildlife and, water (Draft WSBW EIS, USDA FS, 1988). Each forest resource manager decides, based on established management objectives for particular parcels of forestland, what actions are needed to provide the forest condition and productivity desired (Strategic Plan, USDA FS, 1988). Achieving a desired level of productivity generally requires that the basic factors influencing long-term productivity are relatively predictable and that there is a basic understanding of those factors.

There are many resources (factors) that influence long-term productivity, but the basic ones are soil, climate, flora, fauna, humans, and fire (Pfister, 1983). These factors interact and perform a variety of functions, each of which is considered important to the productivity of the forest. If changes in the basic resources occur, the ability of the site to produce a given resource is also changed.

There are productive and destructive processes continually taking place in the forest. Some of these are human caused, but many are natural functions of the ecological resources, such as wind, fire, insects, decay, etc. Many types of disturbances, whether natural or human-caused, have an effect on forest development (Oliver and Larson, 1990). Because sustaining productivity requires a basic understanding of the cumulative effects of environmental factors and management activities on the resource base, there is a need to periodically reassess the general health of the forest. Assessment of the health of the Blue Mountains can help to ensure that management practices are sound, socially acceptable, and appropriate to future needs.

Since long-term productivity depends on maintaining the basic ecosystem resources and their function, it is important that some agreement is reached as to what (and how much) is being produced. In trying to define long-term productivity as it relates to the idea of forest and ecosystem health, one finds that there is no simple definition. Problems arise when attempts are made to find and quantify one universal measure for the potential productivity of any given site (McQuillan, 1983).

An excerpt from a recent publication by J.H. Beuter, and K.N. Johnson (1989),states the dilemma well:

> "But how does ecosystem productivity relate to timber productivity? The distinction can be confusing. Many people equate the two, which makes sense as long as one assumes a direct relationship between what is proposed for maintaining ecosystem health and what is needed to produce merchantable timber. But what happens when the focus shifts from board feet per acre per year to nonmarketable concepts such as nutrient cycling rates, diversity and quantity of soil organisms, and diversity of flora and fauna?"
>
> "This shift is troubling for timber managers. The relationship between ecosystem and timber productivity blurs with proposals to set aside ... acres ..., with restrictions on herbicides and burning, or with other regulations that raise the cost of timber management and thus decrease, rather than increase, timber productivity."
>
> "Long-term productivity depends on maintaining and controlling basic ecosystem process and characteristics-nutrient cycling, soil biology and properties, erosion, and ecological diversity. There are all sorts of implications for how we might define ecosystem productivity and the measures needed to protect it in the long run.".......

Definition

A long-term productivity definition was developed by the USFS Region Six Ecologists in February 1988. It emphasizes the production capability of an ecosystem. The definition states that long-term productivity is the redistribution of resources (heat, light, water, and chemicals) within the ecosystem into products utilized internally by the system or externally by man. Long-term productivity is related to the capacity of an ecosystem to exist and generate products in perpetuity.

Ecosystems are the basic functional units of the landscape. The assemblages of organisms, soil, water and air which form ecosystems also compose the resources we manage. As technical specialists, we know ecosystems are more complex than previously perceived. In spite of at least two decades of intense study, many of the important processes that occur in natural ecosystems are still not well understood. We specialists often have difficulties effectively dealing with this complexity using present technology and operational constraints.

Productivity measurements are made primarily in terms of single resources such as timber, forage, water and wildlife; so there are significant knowledge gaps in measuring total productivity. Fortunately, there are generally accepted methods and units that can be used to measure some of the resources we wish to produce from the forest. The manager must integrate these measurements and judge them in the broader context of maintaining long-term forest productivity.
The ecosystems of the Blue Mountain Forests represent an ideal opportunity for examining and practicing integrated resource management that meet long-term productivity goals. The following is

a brief discussion of some important measurable resources and the factors which influence their productive outputs for the area.

Soil

The Blue Mountain Forests contain a patchy blanket of volcanic ash with properties that strongly influence productivity. Soils in the Blue Mountains are quite variable and may range from those on thin, rocky, low-productivity ridgetop scablands to those in deep ash accumulations on highly productive grand fir sites. Soil differences result from variations in climate, topography, parent material, vegetation, and time. The greatest influence to soils in this area has come from volcanic ash, deposited primarily from Mt. Mazama and Glacier Peak approximately 6,600 and 12,000 years ago, respectively (Fryxell, 1965). Nearly as important, especially in the northern Blue Mountains, has been the deposition of loess (wind-blown sediment) from the central Washington channeled scablands region prior to and following the recession of the Continental Glacier during the Pleistocene (1 million years ago) (Johnson and Simon, 1987). The ash soils of the Blue Mountains region are relatively "young" and minimally weathered, even after 6,600 years, about the time of the last major volcanic influence (Fenneman, 1931). This is evidenced by weakly developed soil profiles, low clay contents, the absence of weathering of primary mineral crystals, and the gradual nature of elemental distribution (Rai, 1971).

Ash has a high water-holding capacity and yields this water to plants with relative ease. Ash also tends to be deeper on the heavily forested sites and shallow or absent on non-forested sites common to ridges and south facing slopes. These soils have a thin litter layer and relatively shallow layer of organic accumulation (Geist and Ehmer, 1977).

Distributions of plant communities often follow these broad soil categories. Bluebunch wheatgrass communities, scabland communities, and xeric shrublands occur on soils with small amounts of loess; while Idaho fescue-prairie junegrass, and mesic shrublands occur on soils with larger amounts. The Idaho fescue-bluebunch wheatgrass communities occur on soils between these extremes. Similar patterns are evident in forested plant communities. The presence of ash in soil layers indicates sites capable of supporting stable grand fir or subalpine fir communities. Communities in the Douglas-fir and ponderosa pine series occur on soils with little or no ash influence. Douglas-fir appears to be at a competitive disadvantage with ponderosa pine on residual soils and those with little or no loess influence (Johnson and Simon, 1987).

Measurements of soil productivity are often measurements of soil loss from erosion or mass movement, moisture capacity, amount of compaction, nutrient availability, soil stability, growth indices, etc. Indirectly, loss of soil productivity is also summed in the expression of vegetation response and can be reflected in site quality measurements or measures of plant biomass production.

Productivity of forested and non-forested plant communities is also closely related to ash and loess content in soils. Unique characteristics of ash soils include high water holding capacity, high water infiltration rates, low compactability, high detachability, and disproportionately high amounts of nutrients in upper surface layers. Under undisturbed conditions, these soils support good vegetation cover which protects the ash from erosion. Since the greatest concentration of nutrients occurs in the upper six inches of these soils, even slight erosion can result in significant reduction in productivity.

Chemical processes in the soil create soil profiles that store moisture and nutrients which, in turn, permit root development necessary for more trapping of moisture and nutrients. A forest system depends on a continuous recycling of minerals. Uptake of nutrients by plants is partly dependent on a symbiotic relationship between mycorrihizae fungi and plant roots. The mycorrihizal association is a prerequisite to normal growth of many forest trees.

Extensive logging was conducted in the Blue Mountains before adoption of mitigation strategies, and little knowledge exists about the effects of earlier practices on soil properties (Geist, Hazard, and Seidel, 1989). Timber harvest and grazing activities have the greatest potential for degrading soil productivity. Although mitigation measures can minimize potential adverse efforts, examples of activities that can damage soils are: Road building, skidding, yarding, and site preparation (including scalping, piling, slash burning, and tilling). It appears that residual soil organic matter levels and compaction are the main variables linking management practices to long-term productivity (Powers, et al, 1989)

Nutrients

Ash soils are often more lacking in nutrients available to plants than the basalt- and andesite-derived soils in the area. However, organic matter, total nitrogen, total sulfur, and available phosphorus are contained in disproportionally greater amounts in the surface of both soils (Geist and Strickler, 1978); therefore they need to be protected. Buckhouse and Gaither (1982) also stress the importance of maintaining and enhancing vegetative cover in the Blue Mountains, as this is necessary to ensuring optimal infiltration rate.

Nutrient cycling encompasses many aspects (Stark, 1983): Nutrient input from precipitation, animal movement, dust and weathering; nutrient recycling through decay, rainfall, streamflow, fire, biological fixation, release and loss by bacteria; nutrient loss caused by harvesting, grazing, and deep leaching; nutrient enrichment within the root zone; ion complexing, etc. There are three basic approaches to measuring and studying nutrient cycling: 1) Watershed studies (Tiedemann, Quigley, Anderson, 1988) (Tiedemann et al, 1988), 2) tension lysimetry measurements (monitoring the quality of water in or below the root zone of trees), and 3) zero-tension lysimetry study (measures quality and quantity of water lost below the root zone).

One of the most important questions that need to be addressed in order to understand the functions of ecosystems is that of "stress." Presently, there are studies looking at external influences that cause stress to the system as well as those contributing to self-induced stress. Self-induced stress can be linked to two related conditions: 1) Increased maintenance of respiration as plant biomass accumulates, and 2) reduced availability of nutrients and sometimes water (Waring, 1982). The development of nutrient stress is closely related to how carbon is allocated. Self-induced stress may generally explain why the tree species occupying a given site are eventually replaced by smaller ones that demand fewer nutrients and less light, a pattern commonly observed in forest-succession studies (Waring, 1982). Self-induced stress may therefore partly explain the periodic nature of outbreaks of defoliating insects (Mattson and Addy, 1975).

Forests

Productivity of forest lands is largely defined in terms of site quality which, in turn, is measured by the maximum volume of wood products the land can produce. Wood products such as sawtimber, pulpwood, fuelwood, and other forest products (i.e., yew extracts, huckleberries) are forest outputs where productivity and the quantity/quality relationship are valued. It is important to note that the level of timber harvest is a management decision that may or may not have direct connection to productive potential of the land (although the level of harvest can influence productive potential indirectly, for example, through excessive removal of nutrients) (Perry, 1989). Site quality has not been correlated with the production of other forest products (Daniel, 1979). Indirect measures of site quality include site index measurements, and various vegetational and environmental description approaches. Site quality is influenced by the function of the various ecological factors listed above.

Vigor is probably the most important determining factor in the ability of a tree to resist insects and diseases. Silvicultural treatments that manipulate vegetation in such a way as to maintain vigor or control species composition play a major role in achieving healthy forests and other goals. Tree vigor is directly related to the amount of sunlight received. Although wide spacings and heavy thinnings result in stands with unoccupied growing space, the resulting increase in individual tree size usually leads to higher timber values per acre and more desirable stand structures for many wildlife and recreation uses (Oliver and Larson 1990). Stand structure and composition are variable and have been strongly influenced by past harvesting and fire.

A significant amount of the designated timber volume of the Blue Mountain Forests is being lost to damaging insects and disease. Tree vigor and growth remain less than desired in many areas of the forest. Changes in species composition from ponderosa pine dominance to that of grand fir or Douglas-fir have exacerbated the problem.

The Role of Woody Debris

The contribution of large woody debris is crucial in all forested ecosystems. Woody debris occurs in the form of standing dead trees, downed boles, and large branches. In the short-term, this woody debris may be a nutrient sink, but over the long run it may be a source of nutrients, depending on decomposition of the material (Harmon et al 1986). A strong interaction occurs between the above ground biomass and accumulation of forest soil organic horizons. Organic horizons are important to the input, storage, and cycling stages of important nutrients. It has been documented recently that wood at all stages of decomposition affects productivity (Harvey et al 1987). Dead woody material is an important resource commodity to the functioning forest. It acts as habitat, substrate, and food for a wide variety of species that often have symbiotic relationships affecting long-term productivity.

Dead woody material management is especially important in plant communities that pertain to true fir plant associations. The mesic fir communities generally occupy ashy soils with northerly or easterly aspects. Temperature and moisture relationships are conducive to fungal growth and help break down the woody material quicker than on the drier, warmer, more exposed locations commonly occupied by Douglas-fir, ponderosa pine, juniper, and non-forest vegetation.

In managed systems, woody debris has often been removed. As a result of that removal, productivity, and diversity have been diminished. Retention of woody material on true fir sites is a valuable factor in providing the nutrient source; it is also valued for wildlife (cavity nesters when it stands; burrowing mammals when it is downed).

Grasslands and Shrublands

Grass and shrub vegetation is an extremely important resource for domestic livestock and wildlife in the Blue Mountain Forests. Grasslands and shrublands constitute approximately 35% of the tri-Forest acres; forested range is therefore an important source of forage. On forested ranges forage is transitory, producing best in the years shortly after disturbance (by fire or logging). It becomes less productive as trees reclaim the site. Range production is measured by forage amount, quality, and palatability. Effective range resource management goes beyond those outputs normally associated with range programs: range management is broader than mere livestock grazing. Recreation, water quality and quantity, soil stability, wildlife habitat, and timber are other outputs associated with range management (Quigley et al 1989). Livestock numbers, calf crops, and weight gain are outputs that are important to livestock producers grazing the National Forests. Activities that affect all desired outputs must be analyzed if productivity is to be adequately addressed.

Wildlife

Forest management practices affect wildlife. Just about any individual manipulation of the forest environment can be detrimental to some species and beneficial to others. Ways to assess these impacts and predict the responses of many wildlife species to plant community changes have been documented (Thomas, 1979; Johnson and Simon, 1987).

Managers gauging productive outputs of wildlife may benefit from: (1) measuring plant community changes (temporal, structural, nutritional, etc.) due to disturbances from insects, logging or other factors; 2) quantifying wildlife populations (compared with carrying capacity or population goals); 3) examining cumulative impacts of human or natural change on wildlife; 4) comparing existing habitat amount or population levels against stated goals; 5) identifying and quantifying habitat requirements for target species; and 6) determining wildlife population trends.

Approaches to resolving the integration of timber management with wildlife concerns have taken at least four distinct forms (Morris, Sanders, Holtausen 1989): 1) Timber management guidelines without explicit mention of wildlife habitat needs; 2) guidelines for featured species wildlife; 3) habitat relationship books (Thomas et al 1979) and early attempts at home range or area-level analysis; and 4) evolving analytical systems that attempt to truly integrate timber and wildlife information.

Forest Pests (insects and disease)

Diseases and insects are important components of the Blue Mountain Forests. They are capable of limiting timber production, creating tree hazards in recreation areas, reducing visual quality, affecting wildlife use, creating fire hazards, and influencing watershed properties. But without them and their aid in the nutrient cycling and decay processes, long-term site productivity would be impaired.

Under normal conditions insects and disease play a key role in keeping our forests healthy. Balch (1958), in a summary of world literature on control of forest insects made several pertinent points:

1) Vigorous trees are less vulnerable to insects.
2) Mixed stands are less susceptible to insects.
3) A mosaic of age classes throughout a drainage reduces susceptibility.
4) Generally, silvicultural practices that encourage tree growth also encourage resistance to insects.

Biodiversity

How does biodiversity relate to long-term productivity? Odum (1972) suggests that variety is not merely "the spice of life", but is possibly a necessity. One theory holds that diversity promotes ecosystem stability (Franklin et al 1989).

In a general sense, biodiversity is the variety of life in an area. It includes variety in the genetic systems of populations, the richness of different species, the distribution and abundance of plant and animal communities and ecosystems, and the processes through which all living things interact with one another and with their environment (Salwasser 1989).

An important question is: How much of what kinds of species and communities do people want in particular places, and for how long? The search for practical ways to measure (or provide for) biological diversity will continue for a long time, and the path of that search will lead to many new fields of enquiry. Conservation biology and landscape ecology are two of the newest. For now, there is a need to integrate specific goals for biodiversity into resource management plans at various geographic scales, from individual sites to forests.

Fire

Fire has played an important role in the evolution of natural ecosystems, and it is essential to the perpetuation of many plant communities in the Blue Mountains of eastern Oregon and southeastern Washington (Hall 1974). The role of fire in maintaining production involves, in part, nutrient recycling, energy release, and vegetation dynamics. A result of past fire exclusion has been a change in vegetation patterns, most notably in previously open pine forest which now supports thickets or understories of suppressed true firs and Douglas-fir. This trend raises concerns about: Tree stagnation; vulnerability to insects, disease, and severe wildfires; and diminished forage for wildlife and livestock (Arno 1989).

However, though it has been excluded, fire remains an important factor affecting production and management, and it should be viewed as a tool to be used, rather than as an enemy to be kept at bay. Fire management technology has advanced sufficiently to support reintroduction of fire into management prescriptions. Fire does not necessarily consume all standing or downed trees, logs, and limbs. In underburning operations beneath ponderosa pine and Douglas-fir stands, fire can consume all the downed material, or if prescribed, provide a cool fire which leaves larger material in its wake. Fire use is an important option in managing for long-term productivity of the forest, and it should be considered more frequently.

Summary

Both commodity and noncommodity values are associated with attempting to define levels of outputs that affect long-term productivity. The above list includes but a few of the factors that influence the stability and productivity of forests in the Blue Mountains. Of these, perhaps the most studied is the maintenance of healthy soils, especially in terms of organic matter and structure. The studies have shown this factor to be a key prerequisite to maintaining healthy ecosystems (Perry 1989).

Noncommodity values are difficult to measure and quantify, but they must be taken into account if we are to truly address future needs. The job of balancing resource use against site maintenance to satisfy both short and long-term resource management goals will require predicting and quantifying numerous output levels over time. There needs to be continued effort to define productive potentials for all resources. Current productivity and outputs can then be compared against the potentials in order to help identify ways to maintain or improve long-term productivity.

The following is part of the summary from the Region Six Ecologist's Workshop on Long-term Productivity in February 1988:

> As an agency, our management activities alter many ecosystem features and produce changes in ecosystem function that may not become evident for decades or centuries. The most cost-effective treatments in the short run (i.e., over one rotation or less) may have undesirable consequences over the longer term or in aggregate with other activities. Future generations will face situations of climate and resource demands that we cannot anticipate. Given the unknowns, we as participants feel the wisest course is to maintain options for future decision making.

In summary, we feel the real driving force behind the long-term productivity issue is an ethical one: all of us as professionals and public officials have an ethical (as well as a legal) responsibility to manage public lands for sustained production in perpetuity. The historical experience of other nations clearly shows that the long-term productivity of the land is a basic requirement for national survival, development, and world leadership.

LONG-TERM PRODUCTIVITY AND FOREST HEALTH ISSUES

Issue 1 - **Planning**

Short- and long-range plans should define the specific levels of products and outputs required for analyzing long-term productivity in order to judge results of management activities.

Issue 2 - **Public Involvement**

Universities, industry, government leaders, and the general public at large have contributed extensively to motivating recent changes in forest management. Concepts such as New Perspectives, Land Stewardship, Caring-for-the-Land, Visions-of-the-Future, etc., are affecting the needs, values, and expectations of the National Forests. But these new policies have not yet come into full effect, and certain disagreements in various public sectors and significant economic and social costs accrue when disputes relating to the sustainability of the forests are not resolved. So, the overall vision of a healthy Forest must include maintaining long-term productivity, and the path to that vision lies in innovative approaches, open communications with the public, and strong relationships with user groups.

Issue 3 - **Resource Management**

Knowing how resource management decisions affect long-term productivity requires knowledge of cumulative effects. Therefore, knowing if we are maintaining long-term productivity will depend on monitoring resource outputs and comparing them to the level of productive function of the ecosystem.

Issue 4 - **Pest Prevention and Suppression**

From the long-term productivity standpoint, endemic levels of pests are necessary and essential for proper ecosystem function. The capacity of the forest to protect itself against catastrophic outbreaks of insects depends mainly upon reducing the stress caused by high stand densities and unnatural species compositions. A forest's resistance to change depends upon its resilience and the functioning of ecological resources (soil, climate, flora, and fauna). From the human standpoint, pests can threaten all resources of the forest when endemic levels are exceeded and/or management objectives are endangered.

Issue 5 - **Environmental Analysis**

The struggle to deal with the problems of integrating various resource goals is not over. Trying to predict environmental consequences and make intelligent and defensible choices is a very complex process. There will continue to be a dividing line between optimizing a specific output, and balancing one against multiple resource goals, even if that output is the maintenance of the long-term productivity of the ecosystem. Integrated resource management needs to be the framework upon which each analysis rests.

Issue 7 - **Pest Suppression Technology**

The newest, and probably the most useful, technology will be the application of models in simulating forest landscapes to support integrated resource management and estimate cumulative effects. However, there will continue to be barriers in applying technology, some of which include: Forestry is a long-term operation; there is a great variety of sites to consider; one-sided experiences are often copied and become articles of faith; and it may not be practical for the resource manager to use the technology.

Issue 8 - **Forest Health Monitoring**

Monitoring for long-term productivity will require that definitions be established for outputs relative to both commodity and non-commodity values. It will also require that the basic ecological factors influencing long-term productivity are functioning as desired.

Issue 9 - **Coordination**

Establishing and coordinating multiple resource objectives with neighboring landowners will continue to be a challenge when prescribing management activities. Plans must consider adjacent lands, and be biologically feasible, economically realistic, and defensible if long-term productivity goals are to be reached.

Issue 10 - **The Role of Fire**

Fire has always been a significant ecological force in maintaining the productivity of the Blue Mountain Forests. Prescribed fire can be used as a tool to achieve vegetation management objectives, reduce plant competition, increase nutrients, manipulate species composition, prepare sites for natural or artificial regeneration, develop special habitats, and reduce wildfire.

Issue 11 - **Biodiversity**

Biodiversity relates to long-term productivity in that it includes the genetic systems of populations, the richness of different species, the distribution and abundance of plants and animal communities and ecosystems, and the process as through which all living things interact with one another and with their environment.

Issue 12 - **Long-term Site Productivity**

Considering all the above responses for maintaining long-term productivity that address total ecosystem function, it appears that residual soil organic matter levels and compaction are the main variables in linking management activities to long-term productivity in the Blue Mountains. They should both be carefully studied.

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CHAPTER VI

DIVERSITY

BIODIVERSITY

Definitions

A simple yet complete definition is that "biodiversity is the variety of life and its processes"(Szaro 1990). Another definition states that "biodiversity is the distribution and abundance of different plant and animal communities and species"(USFS PNW R6-1988). And a legal definition from the Federal Register states that biodiversity is "the distribution and abundance of different plant and animal communities and species within the area covered by a land and resource management plan" (Volland 1979).

These definitions are short and not very helpful for resource managers wishing to use a biodiversity definition in their project plans. A more operational definition states that biodiversity "is the variety, distribution and structure of plant and animal communities, including all vegetative stages, arranged in space over time that support self sustaining populations of all natural and desirable naturalized plants and wild animals"(Volland 1979). The key features or elements of this definition are that community structure, composition, distribution and function are important in the understanding of biodiversity.

Biodiversity can be subdivided into three parts: Genetic, species, and landscape diversity. If we are to apply our management efforts to the maintenance or enhancement of biodiversity, then we must understand all three components.

Introduction

Historically, the concept of diversity was considered important because "maximum diversity" was accepted as an expression that described natural and organized communities (Hairston 1959). However, the breadth and importance of biodiversity extends beyond that simple assumption. When decisions concerning the maintenance or enhancement of biodiversity must be made, the term is usually used to describe a stable, late-successional community. Ecological theory as developed by Odum (1969) suggests that as forests mature, diversity increases, i.e., late-successional or "climax" forests possess greater diversity than younger forests. Forests of the Blue Mountains, however, seem to represent a dichotomy. Less diversity is found in the ponderosa pine/pinegrass communities, which are considered to be the "pre-settlement" forest type that is found throughout much of the area. In the absence of fire, these communities can support Douglas-fir and grand fir. As succession progresses, uninterrupted by fire, species diversity increases through mid-seral stages, but declines as late-seral conditions prevail.

Genetic Diversity:

Genetic diversity is the foundation for genetic change, whether it be through natural evolutionary processes or artificial selection in breeding programs. It is the primary factor protecting populations from total catastrophic loss due to unexpected events (Kitzmiller 1988). In order to ensure that our forests have maximum protection from insects and diseases, we need to maintain a diversity within and between populations. In this sense, diversity is needed within and among tree species, shrub species, herbaceous species, non-vascular plants, fungi, soil flora and fauna, wildlife species, and insects and diseases. Management practices will retain genetic diversity if they maintain components of all site-adapted species across all Forest landscapes.

Native tree species in the western United States exist in extremely varied habitats. The native range of a species may extend across plains, coastal mountains with mild and moist climates, and across cold, dry, continental climates. Genetic variation reflects the vast physiographic variation, and creates a region of great genetic diversity for plant species.

Several tree species have large ranges that stretch from coastal climes to the interior Rocky Mountains. Adaptation to these two environments has produced ecotypes in some species, while other species have demonstrated very little adaptive change. The mix of tree species in the Blue Mountains possesses a range of genetic variation, owing largely to the inherent physiographic and climatic heterogeneity of the Blue Mountains region (Franklin and Dyrness 1973; Price 1978). One of the most widely studied conifers in terms of genetic variation is Douglas-fir. Rehfeldt (1984) states that this species demonstrates much genetic variation, i.e., it is a specialist in adapting to varying environmental conditions and, hence, has a great ability to revegetate sites relatively effectively. It is a specialist in that its seed can remain viable over a wide range of latitude and elevation. Ponderosa pine and western larch also harbor much genetic diversity, but exhibit less specialization. Seed transfers for these species may occur over broad areas with little risk of maladaptation. These adaptive skills enable Douglas-fir to occupy many different habitats, accounting for much of the species composition in the Blue Mountains.

A zone of intermediacy for the two varieties of Douglas-fir has been designated, and it exists between the Cascades and the Blue Mountains. (Zavarin and Snajberk 1973). This has been further substantiated by growth and phenology data of Sorenson (1979).

The Blue Mountains also represent a region of intergradation between two true firs: Grand fir and white fir. Considerable research has examined the introgression between these two species, and the region of most interest represents a swath from northeastern Oregon to west-central Idaho (Muller 1938; Lacaze and Tomassone 1967; Daniels 1969; Hamrick and Libby 1972; Zobel 1973; Houkal 1976; Zavarin 1977; Steinhoff 1978; Hall 1982). These studies provide evidence that the intermediacy apparent in the Blue Mountains has a genetic basis. A variety, *A. grandis* var. *lowiana*, or a new species *A. lowiana*, has been proposed, although no taxonomic study has provided sufficient evidence to determine its phylogenetic and systemic placement.

While the Blue Mountains species are typically "interior," (akin to the Rocky Mountain varieties), Ponderosa pine in the Blue Mountains is of the "coastal" variety. By virtue of its extensive distribution, many races have been distinguished in ponderosa pine (Wright 1966; Wang 1977; Madsen and Blake, 1977). The ponderosa pine in the Blue Mountains is considered part of the North Plateau race or provenance (Conkle and Critchfield 1988). There have even been finer divisions within this provenance such as those based on aspect; they are manifested in such attributes as cold-hardiness or monoterpene composition. However, other traits, e.g., susceptibility to disease and insect problems, which are more prevalent east of the Cascades, may have a genetic basis.

Phenotypic variation is also evident in lodgepole pine, a species that does not attain the same importance in the Blue Mountains it holds in the neighboring Rocky Mountains. While most of the subspecies of the Rocky Mountains and the Intermountain region have serotinous cones, most lodgepole pine in the Blue Mountains have non-serotinous cones (Trappe and Harris 1958, Mowat 1960, Fowells 1965). The species has adapted to fire, however, lending strong evidence to support the role of heat-induced seed dispersal, both in serotinous and non-serotinous cones (USDA 1965).

The Blue Mountains are an interesting and complex region, primarily because the area is noted as an important transition zone for several western conifers. Moreover, the climatic and physiographic attributes differ considerably from the other major regions of the western United States, such as, the Cascades and the Great Basin. Surprisingly few studies have examined Blue Mountain ecotypes, despite the obvious variation in the species of the region. Although fitness and adaptability are closely related to variability in conifers (Lundkvist, 1983, Ledig *et al.* 1983), this area is an important reserve of forest genetic resources because of its unique population structures and variability. And because reduction of genetic diversity may affect resilience of ecosystems, maintenance of this diversity, as well as landscape and community diversity, is important.

A number of taxonomic studies involving Douglas-fir have reported a transition zone east of the Cascades, where the coastal type grades into the inland type (Haddock et al. 1967, von Rudloff 1973, Zavarin and Snajberk 1973). Zavarin and Snajberk (1973), using terpene markers, place this zone in Oregon between the Cascades and the Blue Mountains. In a common garden study, Sorensen (1979) observed a strong west-east transition in the size and phenology of seedlings from population samples between the Cascade and Blue Mountains. This zone of transition was further substantiated by Li and Adams (1989), who observed that racial patterns of isozyme variation largely conformed to patterns based on terpenes and quantitative traits. The evolutionary history of Douglas-fir, as revealed through paleobotanical studies, suggests that this transitional zone has resulted from the genetic mixing of the two varieties as they emerged after the Wisconsin glaciation from two refugia (one in the coastal mountains and one in the Rocky Mountains).

Practices which enhance diversity and can have a positive impact on the genetic composition of our Forests are those that provide different successional stages and some variability of management strategies in forested communities; those that provide for establishment of early seral species; those that result in a variety of treatments; and those that tend to change the scale of managed areas and promote a mosaic-landscape.

Species Diversity:

Species diversity addresses the richness and evenness of species. Richness refers to the number of different species occurring within an area. To keep the perspective of "scale," species diversity is categorized as either "alpha," "beta," or "gamma." Alpha diversity addresses the richness of species within a particular habitat or plant/animal community. Beta diversity addresses the richness between habitats or plant/animal communities and effectively provides a measure of heterogeneity in the comparison. Gamma diversity addresses the diversity among ecosystems. Thus we can discern a need to look at a modifying management activity not only for the impact it may provide to a certain area and its various communities, but also to the impact that activity (and similar ones) may have across a broader area in space and time. Through monitoring activities, species diversity can be assessed by observing the trend for richness at the stand level, the watershed level, and the total landscape level.

Evenness refers to the degree of distribution of individuals among the species within an area. Evenness is rated as "high" when individuals are highly distributed. An example of high evenness within a tree species would be the distribution of ponderosa pine in the Blue Mountains, with its wide variation in habitats from Great Basin edge, to canyon bottoms, to high montane slopes. "Low" evenness results when individuals are poorly distributed among a few species. An example in the Blue Mountains would be western white pine.

Landscape Diversity:

Landscape diversity involves spatial relationships. It has three elements: Structural, compositional, and functional.

Vegetation structure, the kinds of structural units, and the vertical and horizontal dimensions of that structure are important landscape attributes. The way vegetation structure provides key habitat for fauna is also part of this element. Patchiness of a given type of vegetation, sizes of the patches, and their juxtaposition and pattern are important to the quality of a diverse landscape. Connectivity is a term used to denote the degree, amount, and quality of vegetation as it provides for gene flow and species distribution. Structure, therefore, affects the genetic variation and the effective population sizes inherent in an area. Dispersion of animals, their ranges, and attributes of their habitats are all affected by the vegetative structure pattern.

Vegetation composition is measured at the landscape level by abundance, density, richness, evenness, and variety of life forms present. A distribution of plant associations, with a variety of communities exhibiting different seral stages and age classes is highly desirable for maximizing the composition diversity of vegetation on a given landscape.

Landscape diversity is addressed in functional or process terms. The perturbations (disturbing processes) which occur naturally, or are human-induced, affect the diversity of vegetation in the short run as well as the long-term. Nutrient cycling, energy flow, and hydrologic processes are all affected by any disturbing activity. The amount of biomass and its productive potential are strongly influenced by the disruption of the functional cycles inherent in plant communities and ecosystems. And functionally, natural selection, degree of mutation and inbreeding, and gene flow are all affected by vegetation health.

The Degree of Protection vs. The Degree of Disturbance: The Blue Mountains National Forests contain a landscape with a wealth of variation that evolved in a disturbed environment. With some exceptions, the majority of the lands on the Blue Mountain Forests were periodically disturbed. Sometimes this disturbance was violent (wind storms, stand-replacing fire, insect epidemics), while at other times it was gentle and periodic (underburning, browsing, riparian flooding). Prudent management emulates natural disturbances to ensure predictable results. Unnatural changes to the landscape have resulted from management activities undertaken without full recognition for the need for certain types of periodic disturbance on the landscape.

There is a need to understand the tolerances of our lands for withstanding differing kinds of management, their ability to rebound with a resilient flora and fauna, and their biological productivity. Contained in that, is the idea that avoiding disturbances by practicing protectionism may lead to more violent perturbations in the long term. For example, the scarce plant we seek to protect may succumb to that very protection if that species requires disturbance for its regenerative success.

All our lands can withstand management. Some can and do require a regular, and relatively severe, degree of disturbance in order to maintain healthy communities of plants and animals. But others can sustain neither very intense nor frequent disturbance. Certain alpine and subalpine ecosystems are especially sensitive, and at the other environmental extreme, our scabland vegetation (located in dry, hot, thin soils) is also very vulnerable to high levels of disturbance. Riparian areas are relatively limited in number, provide high diversity across a narrow profile, and attract humans, birds, and mammals through the bounty they provide. Though resilient for the most part, the riparian plant community is one of the best examples of a type of area where we have mismanaged or have been insensitive with our management practices.

The habitat extremes containing cold-dry and hot-wet environments, as well as those on specialized and thin soils, are not the only places where disturbance should be limited. As one plant community merges with another, a zone of localized species abundance is often created. These are called transition areas, or ecotones. Management of ecotones needs to relate to the sensitivity of the least resilient of the communities in the mix. A highly valued transition area occurs between the forested community and the non-forested community. The forested stand is commonly bordered by a shrubland made up of a mix of non-forest shrub members as well as forest understory shrub members. There may be plants unique to this zone of intergradation as well. Therefore, this is an area of high species diversity with some very specialized habitats, and the species richness is generally high. Disturbance of these forest/non-forest intergrading areas can severely alter these specialized habitats.

In summation regarding disturbance, some disturbance is vital to vegetation for the enhancement of both floral and faunal diversity. Without fire as a regular event in some plant communities, an unnatural condition arises. Such a condition exists in many areas of the three Forests today. In those communities, disturbance is, and has been, a vital occurrence for maintaining vigor and vitality. With total fire protection over the forested landscape, vegetation changes allow endemic pests to become epidemic and create mortality on a scale that permits lightning ignitions to catastrophically modify the landscape. We seek a balance where our management activities emulate the kinds of natural disturbances at a periodicity that is part of a normal cycle. Where natural disturbances have been minimal, a mimicking of that low degree of perturbation is desirable. And where our most sensitive lands occur, "no activity" may be the best alternative.

Fragmentation and Edge: The ecotones, or transition areas between differing plant communities, vary from being naturally abrupt to exhibiting zones of gradual blending. Sometimes the zone of intergradation is a mosaic consisting of the two vegetative units merging in an "interfingering" of insular and peninsular patches. However, regardless of type, these zones of intergradation provide important habitat for animals. They also provide heterogeneity that is important to the overall diversity of the landscape.

In our management of forests we have often created more "edge" to the overall forested landscape. These created edges are not always representative of natural edges (ecotones) since project boundaries may not conform with ecotonal areas. Thus, management-created edges are sharp and tend to provide limited diversity enhancement.

The degree of habitat richness incorporated within an edge is related to the size of the forest stand and the adjacent kinds of plant communities coming together in the ecotone. The species associated with each habitat have a tendency to overlap the edge into the other habitat. Thus, the larger the habitat blocks, the more species will be associated with them, resulting in a richer species diversity along an edge. Habitat richness is highly associated with the degree of contrast in vegetative structure along the edge. The species richness of the ecotone is increased when the contrast is greatest (Thomas 1979). An example of high contrast would be mixed tree species with shrubbery in multi-structural layers adjacent to a grassland. Low contrast might be depicted by a youthful even-aged stand of trees adjacent to a plantation of pole-sized trees resulting from two different harvest periods.

When we fragment the landscape we diminish its homogeneity. This can result in declines of large, wide-ranging fauna and affect the genetic diversity within a species if fragmentation is maintained. If the juxtaposition of the fragments is unplanned, important "corridors" for gene flow and wildlife movements may be constricted or terminated. On our ranger districts, large expanses of forestland occur which are managed for timber production. These are our most productive and most accessible lands for tree growth and tree sustainability. These are also the expanses which we have converted from a semi-continuous forest to a mosaic of residual forested islands and corridors with intervening early seral, single-aged, and single-storied stands. The edges are often abrupt and, in such cases, provide little opportunity for ecotonal development.

The *New Perspectives* philosophy can be employed to help promote biodiversity by championing those management practices that provide desired vegetation, age, structure, and composition patterns on the landscape. Where stand replacement is considered necessary to promote vigorous, healthy stands with greater resistance to insect and disease outbreaks, project-area size and juxtaposition should to be planned for maximizing the benefits for diversification. Such activity would provide for the long-term genetic health, the long-term species composition, the overall structural needs of the landscape, and the functional ability of the vegetation and its biota to continue the process of ecosystem cycling. The activity which gives rise to the stand replacement would also promote "hidden" diversity by retention of downed woody material, larger trees, and tree groups. Retention of these factors would help to provide natural refugia for organisms, and habitat for insects occupying the niche of decomposers in the system. Insects and diseases may be plaguing the Forests at this time, but they play the role of renewers, engendering healthier forests.

No project should be considered complete without careful attention to edges. Silviculturally, a feathered zone should be created to allow for future snag production and a mixing of the untreated understory with the resultant vegetation from the treated area. Visually, the managed patch would appear as part of a heterogeneous landscape where natural openings (meadows, scablands, and shrubfields), as well as managed units, would appear to be equitably distributed and would exhibit a pleasing pattern to the eye.

Scale of Project Implementation: The creation of large expanses of continuous vegetation is a result of both natural and unnatural processes. Geologic formations, soil depths, aspect, elevation, and overall climatic extremes are the principal formative factors giving vegetative uniformity to large-scale landscapes. The same factors can create large-scale heterogeneity. The key modifier of vegetation is environmental change. Grasslands in our canyons are examples of large expanses of a certain lifeform, but these often are highly varied when viewed at the plant community level.

Examples of unnatural events which have promoted homogeneity are railroad logging, large hot fires, lack of periodic surface fire, and uniform silvicultural treatments on a large scale, e.g., overstory removals in large extensive units. Some of these same events have promoted a high level of heterogeneity that has fragmented the forested landscape; i.e., they have made a mosaic of silvicultural treatments, small stand replacement fires, and salvage operations.

Management resulting in new patterns on the land is desired in order to provide diverse patches at scales similar to those resulting from natural landscape features. Stand replacement operations can permit fire and/or silvicultural treatments to provide non-forested openings, young stands of pioneering tree species, and the fauna that is promoted by earlier seral vegetation in a forested landscape. Other projects can help to create highly selective operations keyed to the promotion or retention of specific plants, animals or community fragments. In appropriate communities, projects can also provide underburning to retain pine dominance and call for uneven-aged harvest strategies. As we implement these management strategies, planned fire use should increase, large tree harvest should decrease, salvage operations should be limited, and natural regeneration should be fostered. The use of exotic vegetation species for reseeding an area after a fire event and the subsequent silvicultural operations, should cease. Managers should rely on the native grass, sedge, shrub, and forb species to provide pioneering communities following heavier disturbances.

Diversity Management Priorities

The entire National Forest landscape is available for implementing biodiversity management strategies, and prescribed fire and other management activities could be used on reserved lands to modify communities and provide rejuvenation and variation. However, there are certain portions of the lands we administer that should probably be given higher priority, such as areas where an absence of fire has created unnatural fuel loading, unnatural stands, and epidemic pest outbreaks. Other management foci might be those areas where the presence of sensitive plant and animal species are likely, and those heavily impacted lands where rehabilitation efforts are needed to help re-create the structural, species, and landscape diversity that has been lost.

Old Growth:

Climax, late-successional, undisturbed, virgin, mature, over-mature, and ancient -- are terms that have been used in definitions of old-growth forests. Hunter (1989) maintains that local ecology and disturbance history must both be taken into account when defining old growth. In this regard, and despite the fire-climate of the Blue Mountains, some old-growth stands do in fact occur. Traditional views of old growth, including the large-diameter tree component, do not necessarily apply to the Blue Mountains (Old Growth Definitions Task Group 1986).

Other definitions of old growth may be more applicable to the Blue Mountains. For example, Thomas *et al.* (1988) described old growth in terms of diversity of structure and function, not merely in terms of diversity of species. Hall and Thomas (1979) discussed old growth in terms of stand age, taking into account the lifespans of Blue Mountains species.

Much of the extant old growth in the Pacific Northwest has been "fragmented" by various management strategies and human exploitation (Harris 1984, Franklin and Forman 1987). Biotic constituents of such areas are highly sensitive to changes imposed by management practices, and populations of adapted species have been significantly affected by fragmentation.

The old-growth "issue" has recently become important in terms of the CO_2 storage capability of these forests. Some argue that conversion of old growth to young, fast growing forests will actually cause more absorption of CO_2. Considerable evidence exists, however, to suggest that forest conversion will not appreciably decrease atmospheric CO_2 (Harmon 1990).

One aspect of diversity (that of a stable, long-lived (old growth) plant community) is often termed "climax;" however interpreting "climax" as a stable-state plant community (Oosting 1958, Daubenmire and Daubenmire 1968, Christensen 1988) leads to certain contradictions. The term "steady-state condition" suggests that vegetation types are self-perpetuating, but also in a balanced state with environmental conditions and organism populations. In the Blue Mountains, grand fir and Douglas-fir are self-perpetuating members of the forest community, but the stability of the ecosystems in which these species are a major component may be questionable since these stands appear to be the most susceptible to insect and disease outbreaks.

The haphazard nature of fire occurrence sometimes permits late-seral stands to develop through avoiding mortal crown fires. As we have intensified our timber harvest operations, the acreage of these "old-growth" stands has diminished. In addition to providing critical habitat for wildlife species, such areas are necessary, both genetically and ecologically. It is therefore important that old-growth stands be a component in the forest environment; further, it is necessary that these stands be equitably distributed, of sufficient size, and located throughout a variety of plant associations.

The selection of dedicated old-growth stands in those areas where harvest activities have been limited, or where timber harvest has not occurred, may not ensure that distribution and variation are properly taken into account. In the areas where disturbances have been frequent and of high intensity, there will be a need to develop stands for future old-growth characterization. Additionally, more old-growth replacement stands will be required as designated old growth is lost to catastrophic events (e.g., windthrow, insects, and fire).

Since old-growth stands are the result of limited disturbance over the long-term, promotion of old-growth characteristics will require patience and dedication on the part of land managers. Old growth does not develop in a decade. Therefore, strategic planning will be necessary to promote the retention and promotion of late-seral stands. Maintenance of old growth may require a degree of silvicultural treatment in some plant communities. Old growth may be best preserved by enhancing tree vigor via stocking control. An aggressive uneven-aged management program that includes diversity planning can bring about the building old-growth components in the needed places, in appropriate measure, and before any efforts are too late. If such factors are taken into account, timber harvest plans would reflect the need to safeguard and rebuild a landscape diversity that includes all structural components.

Rangeland Diversity:

Rangelands have gained attention at the national level. Issues have arisen regarding their ability to produce, their suitability for use, and their overall quality. Certain rangelands have received greater amounts of concern than others, e.g., riparian "zones", forest plantations, and gentle benchlands or ridges and where damage has occurred. Such damage has usually been ascribed to the actions of sheep, cows, elk, and humans. The main point of this issue regards the role of disturbance activities in creating healthy plant and animal communities and promoting biodiversity.

Utilization and periodic burning is important in the maintenance of vigorous bunchgrasses in communities where they are principal components. In addition, animal grazing, because it is a selective process, provides stimuli to certain plants and reductions in others. "Proper" grazing is a tool land managers can use, along with prescribed fire, to promote certain stages of succession and influence the biotic communities associated with rangelands.

The condition of our grasslands, shrublands, and riparian communities is strongly influenced by the season of use, the intensity of use, and the kinds of users. Generally, cattle and elk have complemented one another in areas where they have grazed mid- and late-successional grasslands. Where early-seral and very-early-seral grasslands were grazed by both, neither the rangeland nor the animals have benefited. The removal of grazing animals from rangelands could be detrimental to bunchgrass vegetation in the same way that a prolonged absence of fire will foster decadence and pestilence in stands of trees. Bunchgrass vegetation excluded from ungulate use has demonstrated the need for another stimulus for propagation and growth.

Past overgrazing has resulted in expanses of very-early-seral vegetation with lower diversity components (e.g., Kentucky bluegrass benchlands, tarweed ridgetop flats). As with forested expanses, grasslands also require management toward mid- and late-seral vegetation development. Reduction in use, changes in kind of use, different seasons of use, and rehabilitation projects are some of the ways to promote a change in trend toward late-seral stage vegetation development. The resting of vegetation through deferred- and rest-rotation systems can help stimulate positive vegetation change. Prescribed fire will help rejuvenate grasslands and shrublands, and increase forb composition.

Wetlands - A Special Diversity Consideration:

A definition of resilience is "the ability to absorb stress and maintain productivity." Wetlands (riparian areas, meadows, marshes, etc.) have often been thought of as being resilient. However, as the western United States was settled and the agrarian homesteaders made their mark on the land, the attraction to riparian areas on the landscape was great and so, consequently, were the marks left. There, settlers and animals alike found the sustenance to survive the summer droughts of the inland Pacific Northwest. As grazing increased, there was not much environmental concern, and there was a certain amount of naivety regarding impacts that would result from the overgrazing. People then felt, as they often do now, that short-term gains were of paramount importance.

We know today that wetlands are subject to periodic disturbance (e.g., flooding, landform changes). Many of these disturbances are desirable from the standpoint of rejuvenating the riparian ecosystem. Floods and floodplains go together; without periodic flooding, diversity and stability are lessened. Beavers are important to the vitality of several riparian systems in the Blue Mountains. The loss of beaver in riparian areas has resulted in the loss of periodic disturbance required to enhance the streamside diversity, provide community vigor, and enhance landscape complexity. The general condition of riparian vegetation, riparian fauna, and riparian hydrologic regimes is poor-to-very-poor throughout many of our lower- and mid-elevation streams and rivers. They are not as "resilient" as we once thought. Selective grazing by domestic and wild ungulates has impoverished many plant communities and species along stream reaches. Diversity has declined and species extirpation has been the result in many riparian areas. Aggressive colonizers have overtaken habitats where native species have been weakened and lost.

In order to initiate management changes for rehabilitating the riparian ecosystem on the Forests, a strong coordination with watershed specialists, fisheries and wildlife biologists, and rangeland conservationists should be established. Interdisciplinary planning for long-term activities to enhance upland diversity should also include the local riparian areas.

Once again, exclusion of natural forces is not the answer. The historic events that have shaped and encouraged both geomorphic and vegetative attributes of a given riparian system are necessary for overall health and must continue. Where species and landscape diversity elements are lacking, the improvement and promotion of key *floral* and *faunal* species are desirable for enhancing biodiversity.

Rebuilding Structural Diversity in Forest Stands:

We can promote insect and disease-tolerant tree species by underburning or through using discrimination in thinning prescriptions. By hot burning some areas within underburned forest landscapes, we can introduce interplantings of other species to build better future tree mixtures. Through subsequent silvicultural work designed to vary tree sapling densities, we can promote either shade-tolerant or shade-intolerant species and foster the improvement of structural diversity as well as improving stocking of key tree species.

Sites need not be reforested with common coniferous species. Biodiversity is enhanced when hardwoods are reintroduced to certain Blue Mountain plant associations. Species such as cottonwood, willow, maple, aspen, and alder are native in early and mid seral components of forested communities. Therefore, the presence of hardwoods and shrubs should be viewed as complementary and important to the long-term health of the forested landscape.

A creative way of retaining trees to maximize diversity has been suggested by the Hells Canyon NRA silvicultural unit. They propose to select trees for long-term retention that demonstrate good crown ratio, good leader growth, and which are apparently free from damaging pests. These trees are to be marked and posted for their "diversity value." Regeneration that would compete with these trees will be reduced or eliminated. The "diversity trees" are to be managed on a longer rotation cycle than other trees in a stand. This idea promotes the use of uneven-aged management, and provides a means of introducing a stable element in managed stands that would also enhance genetic and species diversity.

Perhaps the most fundamental requirement in rebuilding healthy forests through the improvement of the various kinds of diversity would be filled by lengthening rotation ages within many forest groupings. If entries for extractive activities are limited, groupings of different forest stands will tend to perform more naturally, and will thereby provide the genetic, species, and landscape functions required to improve biodiversity.

Wildlife Needs:

The health and thrift of wildlife populations in the Blue Mountains are predicated on the vegetation conditions present, including species composition, distribution, and structure. Vegetation in the Blue Mountains is a reflection of environmental conditions. The primary influences are moisture gradients and those biotic factors which affect plant species and their capability to survive and establish communities. Prior to the introduction of human influences, Blue Mountains vegetation responded to, and established plant communities in, certain soils and topographic settings within moisture gradients, fire sequences, and perturbations caused by endemic levels of insects and disease.

Wildlife populations, insects, and disease all respond to changes in vegetation conditions. The most responsive wildlife populations are those associated with early- and mid-seral plant communities. Other species that are considered to be highly responsive to changes in forest composition or spatial organization of plant communities are the large predators (bear, cougar, and wolf) and cavity-dependent wildlife.

If we accept the assumption that past changes in wildlife populations, or at least some factions of the present-day wildlife spectrum, are the direct result of changes in forest composition, structure, and distribution, then we must assume that changes in forest composition that tend to "mimic" natural forces and restore forest health will have an effect on wildlife species which co-evolved with those forest types. Therefore, it is likely that vegetation management designed to promote forest health will be reflected to some extent by changes in faunal species populations. For instance, the reintroduction of fire will reduce tree understory thickets and increase the shrub component on those lands where it is applied. Such an activity will probably lead to increases in deer populations and decreases in elk populations.

Other populations can be affected by more "natural" management schemes as well. For example, recent research demonstrates the value of "wildlife trees" (especially in the fir associations) for providing nesting, feeding, and denning habitat for cavity-dependent birds and forest mammals. Large diameter true fir with heart rot, and large down woody material are also parts of the habitat requirements for these species. These habitat components can be provided (and, therefore, the species populations increased) by using current technology, research data, and silvicultural options available for restoring forest health.

The most significant changes in forest composition and structure in the Blue Mountains have occurred in the pine/Douglas-fir associations where "fire exclusion" and selective harvest have left a mixture of shade-tolerant conifer species and over-stocked stands. Repeated insect defoliation of shade-tolerant species in these plant communities has resulted in reduced thermal cover for big game, and the accumulated down-and-dead material, particularly in the lodgepole types, has forced elk to use other habitats. In the future, within these low- to mid-elevation plant communities, a restoration of forest health will tend to favor the pine because it has evolved to survive under difficult moisture regimes. Fire and other vegetation management techniques may be used on such sites to increase the health and thrift of pine species and reduce stocking density. If such practices are used, thermal cover quality on pine sites will probably be reduced, but the reduction of down-and-dead material will increase available hiding cover and forage. Moreover, prescribed fire can greatly enhance the availability and quality of elk forage.

The effect of restoring forest health within the pine/Douglas-fir communities should not result in any significant reduction in elk habitat capability, considering the end result will be higher quality forage, reduced down-and-dead material, and a healthy forest canopy. Furthermore, within those communities, a judicious access-management program can increase elk habitat capability and provide elk habitat capability coefficients that exceed present-day standards.

True fir (grand and subalpine) stands provide wildlife with a different set of habitat requirements, such as thermal cover for deer and elk, and dwelling and feeding sites for cavity nesters. When fires replace these stands, wildlife is provided with new structural habitat (shrublands, even-aged thickets) and tree compositional changes occur (larch, lodgepole pine). Management of true fir stands to promote biodiversity requires that stand-replacing activities contain provisions for leaving downed woody material, standing dead snags, standing future snags, and old growth units in proximity to managed even-aged units.

Wildlife trees and large woody material will be the most challenging habitat components to retain in the pine communities, especially where prescribed fire is used. However, current research has provided data that can be used to establish the numbers of snags and volume of standing dead or down-and-dead woody material that will be required in a given area, and current techniques can be implemented to retain these components while using fire to manage forest composition and stand density. The effect of establishing required habitat parameters for pine-associated wildlife, while restoring forest health, should be significant increases in habitat capability. A greater understanding and enhancement of forest health should result from this process of using combinations of current techniques and data.

The Need for a New Perspective

In order to achieve long-term biodiversity goals, management needs to build an attitude and philosophy that seeks ways to mimic both the natural heterogeneity of the physiographic setting and the natural pattern of disturbances inherent in the landscape. It is the latter task that will be most difficult. The use of fire and silviculture as basic tools is possible with the skills presently available in our workforce; moreover, education and on-the-job training will improve all disciplines' skill levels. Our most difficult task lies in assessing when, where, and how to conduct management which promotes the diversity we envision. Certainly we will need to draw on the wisdom of local "historians" who can provide the background information on how a particular landscape appeared prior to the turn of the century. Then we will need to draw on the talents of ecologists, wildlife biologists, fuels specialists, silviculturists and landscape architects to design each activity. The shifting emphasis from stand management to landscape management might require redesigning our unit workforces to include more employees who work in areas that stress enhancement activities rather than extractive activities.

The size of our timber harvest units has sometimes resulted in small, isolated stands rather than in larger units which could enhance the diverse offering of the landscape. The result of small, isolated patches is a reduction in the available habitat. These do not help provide a complex of multi-seral stands capable of affecting population sizes, dispersion, and landscape pattern. The other extreme occurs when extensive clearcutting has been conducted across a particular landscape. Natural ecotonal features are lost completely by these large-scale harvests. Since the 1970's, intensive harvesting of dominant tree overstories has occurred on many mixed coniferous stands that were dominated by pine. In some areas, harvests have resulted in large extensions of homogeneous forestland across the landscape, causing a reduction of attributes needed for structural diversity, genetic diversity, and species diversity.

The key is to find a balance between the total lack of perturbating events (whereby no means of promoting vigor, vitality, or diversity are implemented), and the combination of natural and human-caused disturbances that are conducive to improving the three diversities--genetic, species and landscape. In order to accomplish this, there are three general guidelines to be followed: First, we shift to an emphasis on the management of ecosystems (as opposed to our stand-emphasis of the past); consequently we will leave some unsanitary trees, stands, and landscapes. Second, because the harvest of tree overstories results in a loss of structural, compositional, and functional landscape diversity features, we will need to invest in project work that will provide enhancement of managed stands. Third, diversity-enhancing activities should be conducted on unmanaged "suitable" timberlands.

Mimicking nature is an art that requires creative people who are willing to experiment. As their visions are implemented, we will begin to learn how a particular landscape changes to fit patterns that enhance the species and structural make-up of a given land unit. The learning process and its effects will be long-term as we come into a more complete understanding of what it means to manage forest resources for diversity. And in order to accomplish this goal, it may be that we should restructure two areas within the organization:

First, planning to improve the three kinds of diversity discussed earlier in this report requires adoption of a different perspective than was held by past management regimes. Instead of looking ahead 5-10 years for areas where we can and should harvest trees and attain our planned timber yield, we need to look farther into the future and prepare plans for how we will manage entire landscapes. Projects should be strategically planned over a much longer timeframe, a timeframe that is based on periodic rejuvenation by perturbating events that have historically modified the various kinds of communities. Within the scale and time constraints that govern natural perturbations, planners could determine where to leave and maintain late-seral vegetation (old growth), where to plan for future old growth, and where to culture stands for improving structural diversity in areas that require more mosaic than currently exists. The salvage of pest-damaged trees and timber stands could be tempered by the need to provide "residual" patches as well as modified (harvested) patches in the landscape mosaic. Taking all of the foregoing into account, the job that these planners perform would be an ongoing, dynamic process. It should probably begin with a base plan which would receive periodic modifications in response to wildfires, wind storms, floods, and other unexpected natural events.

Secondly, there is a need to monitor the management-induced changes on a more intense level than has been the case historically. The health of the Forests must regularly be addressed. Doing that could require that we document the changes in permanently established locations for long-term follow-up and assessment. Monitoring is a primary duty, not secondary or periodic. It needs to be cyclic and consistently accurate for timely and trustworthy results. This may require trained seasonal crews to work in multi-resource evaluation on an annual basis, receiving the kind of fiscal support we now afford stand examination crews. Examples of the kind of work might be as follows: Acquiring stand and community structural data for construction of diversity indices; plot establishment following prescribed fire to measure responses to varying intensities of fire through different plant associations; performing wildlife surveys before and after treatments to assess short- and long-term animal response to habitat modifications; and assuring through investigative surveys that sensitive species are being enhanced by management activities that are supposed to encourage them.

BIODIVERSITY AND FOREST HEALTH ISSUES

Issue 1 - **Planning**

Forest Plans currently address the needs for diversity through management of Research Natural Areas, Old-growth, Backcountry, Wilderness, Wild and Scenic Rivers, and Big Game Habitat Allocations. In addition, Standards and Guidelines in commodity-emphasis Management Allocations include direction for enhancing diversity, e.g., snag-management requirements. Although these management requirements supply an abundance of diversity, it is not clearly understood how they address the broad questions of genetic, species, and landscape diversity across the Blue Mountains. If we are to change emphasis from stand management to landscape management we need to address the needs of the ecosystem, its functions, and its processes. Planning is required which calls for lengthening rotations in some areas, increasing disturbances, changing the scale and cycle of disturbances, enhancing structural diversity, changing management techniques, and other possible alterations with the goal of improving the biologic diversity of the Forests. In order to achieve healthier Forests, planning is needed at the ranger district level of the organization which will strategically promote those activities and treatments which help in developing the mosaic of vegetation needed to enhance, create, and maintain biodiversity and long-term site productivity. The level of planning requires that the inherent characteristics of plant communities and their associated fauna be understood. Knowledge of how these communities relate to disturbance as well as how that disturbance can enhance biodiversity and overall Forest health is fundamental to any plan that addresses ecosystem vitality. Because this understanding is so important, the functional needs of the planning teams may include the use of specialists to address the values provided by multi-seral vegetation mosaics. Finally, it is of paramount importance that the planning teams place their evaluations and designs in the context of the scale and timeframes associated with the natural growth and cyclic perturbations of a given area.

Plans should address genetic, landscape, and species diversity. Projects should be designed to meet the objectives of biodiversity enhancement as dictated by the desired future condition, even though the projects which are funded and the targets which are set may provide minimal short-term economic return. Enhancement and improvement activities are the short-term vehicles we intend to use to rectify and promote disturbances which encourage ecosystem health. Three principal areas of diversity management need to be encouraged at the outset; these are: (1) Lands where sensitive species are known to reside; (2) lands requiring rehabilitation; and (3) lands where a lack of natural disturbances has created unnatural conditions.

Issue 2 - **Public Involvement**

We are likely to make mistakes as we change management policies from familiar practices to innovative ones designed to achieve a variation which includes, among other goals, the maintenance of endemic levels of insects and diseases. An educational effort is encouraged which would include a recognition of those mistakes and the fact that we will not achieve our management goals for improving the overall health of the Forests in just a few years. The timeline will be dictated by the developmental requirements of each patch in the overall Forest mosaic. Therefore, it may take 100 years in some parts of the Forests to achieve desired future condition, while less resilient communities residing where environmental extremes dictate a slower change, may take 200-300 years.

The public may not understand why we will allow merchantable trees to burn, and why we may change overall timber production as well as the dimensions of our harvested materials. Philosophically they may accept the pretext upon which all the management decisions are based, but in practicality they may see some short-term economic losses resulting from our rehabilitative and enhancement projects. Our job is to begin to spend the energy, money, and time necessary to impart a message to the public that these departures from past land management practices are necessary and vital to the forested ecosystem.

Education is needed to provide an understanding that the native pests have evolved over a long period of time. And even though protection of timber crops from fire and pests has long been our primary objective, that objective has now changed. We now desire to improve the capability of the forest, riparian, grassland and shrubland ecosystems, so that they function more naturally and, in so doing, ward off the degrading calamities that have befallen them. The message is that a possible economic downturn, if it comes, will be of short duration. Extracted goods will continue to flow from the National Forests. Any types of product losses will be tempered by the improvements in overall health and the increase in productivity from successful rehabilitative efforts.

An educational effort could also be initiated from the National level. Messages that create changes in opinion regarding the vision of the healthy forest should be a primary goal. That vision would include the view that endemic levels of insects are a natural part of the Forests. The increase in early seral vegetation as a result of overgrazing needs to be projected as an undesirable detractor of the biodiversity needs of the Forests. At the same time, must be shown to be degraded by protection from perturbating events.

Issue 3 - **Resource Management**

The current insect and disease situation has arisen from lack of fire in those forest ecosystems which historically included fire as a periodic and cyclic event. The pest problems have been further aggravated by drought conditions resulting in poorer tree vigor and favoring the insects and diseases which have multiplied in numbers and severity. Also contributing to the problem has been the long time harvesting of pine, and the culturing of fir by silvicultural design and stand protection from fire. In order to assure that we begin to turn the tide on pest epidemics, we will need to manage for multiple ages in pine sites, leave structural fragments in even-aged management areas, and change the scale of management areas to achieve the needs of species, genetic, and landscape diversity. Old-growth areas of sufficient size need to be distributed equitably throughout the variation of plant associations represented on a particular landscape. Replacement stands for old growth lost to unplanned events need to be strategically located and encouraged to develop unhampered. Old growth also needs to be actively maintained to assure vigor and pest resistance.

Timber harvest may need to be reduced for the short-term because inventory figures have not taken full account of the mortality losses caused by insects and diseases. In addition, the previous inventory utilized projected growth on potential crop trees which have either succumbed, lost incremental growth, or will be lost to the cultural practices employed to promote biodiversity. Harvest may also need to be reduced to accommodate the necessary reduction in available harvestable acreage resulting from implementation of biodiversity oriented projects. Enhancing diversity entails an increase in rotation which results from the shifting of harvest from when trees cease maximizing incremental growth to when trees can be taken based on the more natural cycle of tree mortality. However, this would also beneficially affect the volume of timber product provided over the longer term.

As we shift management from stand emphasis to ecosystem emphasis, wildlife should benefit from the resulting greater variety of habitat. By promoting structural diversity on a landscape management scale, wildlife should respond with greater richness and evenness throughout the three Forests. It is also possible that insects and disease problems would continue in the shortrun.

Riparian areas are enhanced by the ecosystem approach. The specialists who would work on the District plans for achieving greater diversity and overall health of the Forests should include those specialists historically concerned with fish, streams, and ungulates. The focus would be on improving landscape units which include wetlands as well as uplands. Projects should not be undertaken that do not integrate the needs of the unit as a whole in enhancing, maintaining, or creating activities designed to improve the plant and animal communities of the Forests.

Issue 4 - **Pest Prevention and Suppression**

The spraying and/or harvesting of pest damaged trees does not stop epidemics in the Blue Mountains. To stem epidemics, a variety of management activities should be conducted to increase structural and landscape diversity, thereby attacking the cause of the problem. The use of fire to underburn and replacement burn, and the use of silvicultural prescriptions designed to achieve species compositional changes, structural changes and, in the larger context, changes in patterns across the landscape are examples of non-chemical treatments for suppression. The provision of more habitat for cavity nesters can also help to promote natural insect predation.

Issue 5 - **Environmental Analysis**

The use of an area analysis concept with expansion to the District scale can increase the ability to assure that biodiversity is addressed in project planning.

Issue 6 - **Pesticides**

Chemical use can be a short-term solution in localized situations. For example, herbicidal use can improve tree vigor by killing or reducing the competition from undesired vegetation. Pesticides can control outbreaks where high value stands are imperiled by insects.

Issue 7 - **Pest Suppression Technology**

The combined use of fire and silviculture in integrated pest management to promote patches of mixed age classes, and stimulate greater landscape, species, and genetic diversity may provide the best protection from epidemic outbreaks. The scale of our management activities needs to be planned at a size which maximizes diversification without compromising gene flow, natural species selection, site productivity, or retention of stable communities. Diverse communities will include some endemic level of insect and disease occurrence. Mortality associated with these levels of insects and diseases will provide for a variety of living organisms, and epidemic outbreaks will be less of a threat than current conditions allow. The management of pests in the vegetational mosaic will be similar to, and reflect, the management of fire in that same mosaic.

Issue 8 - **Forest Health Monitoring**

We do not know all we need to know in order to practice ecosystem management. We will make mistakes. We must learn from these mistakes. As we implement activities designed to leave as well as take, we need to chart the mosaic and measure its attributes. We can use photographs taken from airplanes, the ground, and satellites to help interpret changes on the land over time. The landscape we are required to monitor is large. We must remember that the District is only one section of a whole. The Forest is yet another section of that whole.

Monitoring activities are ideally initiated before an activity and should not conclude for many years when seeking to learn the changes wrought by a given diversity-enhancing activity. The management approach to a desired future condition transcends the human lifespan. Adequate ecosystem management, biodiversity management, and assessment of long term productivity take timeframes that transcend the careers of most employees. The monitoring for Forest health may include progeny testing, species abundance inventories, vegetation trend measurements, structural analyses, and studies of mosaic variation flow.

Issue 9 - **Coordination**

Federally administered lands are like islands within State and private ownerships. Therefore, it will be important that we work with State, private, and other Federal agencies to help promote the changes we will be making. We will need to coordinate with State extension foresters, small woodlot organizations, BLM, SCS, Native Americans, and others.

Issue 10 - **The Role of Fire**

We need to reintroduce fire to its historic role of modifying and rejuvenating our national forest lands. In order to accomplish this, we must commit to a fundamental management shift, concentrating on ecosystem management as opposed to single tree and stand manipulation. Moreover, we need to initiate a campaign designed to promote understanding at all public levels showing that fire is, in fact, a "protector". Its regular presence ameliorates the negative effects of disease, insect attacks, tree decadence, and conflagration, and by aiding in these causes, it promotes the production of all resources.

Issue 11 - **Biodiversity**

Fire and the physiographic setting have combined to provide the three Forests with a high degree of variation in plant and animal life. Loss of species, increase in homogeneity, and breakdown in natural processes are reasons enough to embark on a change in overall management philosophy and application. We need to impart a message that we are shifting from exploitive forest practices, which have taught us the limitations an ecosystem can sustain, and that we are embarking on a more limited extractive approach in order to build back some of the diversity which has been lost. We need to demonstrate a proactive stance, not a reactive stance stemming from external group pressure. The recent R-6 impetus to conduct a large-scale biodiversity workshop attended by a large cross section of employees from throughout the Region is reflective of the kind of action we need to demonstrate.

Issue 12 - **Long-Term Site Productivity**

Enhancement of long-term productivity results from going lighter on the land, entering less frequently into units for project work (especially when heavy equipment is employed), and leaving biomass behind to decompose and add to the nutrient bank. Employing those activities that cover the land less intensively in the creation of landscape diversity should help to improve the overall productivity of the land and overall health of the Forests.

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APPENDICES

APPENDIX A

FOREST PLAN INTEGRATED PEST MANAGEMENT DIRECTION - WAW, UMA, MAL NF's

This section includes excerpts of management direction from each Forest Plan related to IPM. It does not include all of the direction that influences the health of the forest.

Timber or Timber and Wildlife Allocations

Management Area 1 (WAW)
Management Area 3 (WAW)
General Forest 1 (MAL)
Timber and Forage E1 (UMA)
Timber and Big Game E2 (UMA)

WAW 1 - Prevent/suppress pests using IPM techniques when outbreaks threaten resource management objectives. Examples are: stump treatment for root disease, pesticide applications for defoliators and cone insects, early harvest, stocking level control, and species manipulation. Economics will be considered including no action. (FP 4-58)

WAW 3 - same as Management Area 1. (FP 4-62)

MAL - Continually monitor pest populations and implement activities to prevent development of epidemics. Aggressively suppress pests when outbreaks threaten timber management objectives. (FP 4-51)

UMA E1 - Use IPM principles and strategies in managing pests to meet management objectives. Monitoring and detection of pest conditions and populations will be done so that corrective treatments consistent with resource objectives can be prescribed at the earliest opportunity. (FP 4-181)

UMA E2 - Use IPM principles and strategies in managing pests to meet management objectives. Monitoring and detection of pest conditions and populations will be done so that corrective treatments consistent with resource objectives can be prescribed at the earliest opportunity. Protect growing stock consistent with the level of investment by practicing high intensity prevention activities.

Emphasis will be on the prevention of stand and fuel conditions that favor pest increases above epidemic levels. Aggressively suppress pests using the most cost-effective suppression strategies when outbreaks threaten resource management objectives. Use a variety of methods (IPM) in meeting protection and suppression requirements. (FP 4-186).

Record of Decision

WAW

a. Insect epidemics/fires require ASQ recalculation. This will follow 1992 Forest-wide inventory. (ROD 8, 22)

b. Silvicultural systems will normally use even-aged management. (ROD 21)

c. Attempt to achieve an HEI of 0.5 in management area 1. If not possible, timber sale planning document will explain why. Timber sale volumes will not be reduced to achieve this objective. (ROD 12)

UMA

a. Silvicultural systems will normally use even-aged management. (ROD 14)

b. Pest Management- IPM are used to prevent and control pests through vegetation management activities (Prevention); early detection and aggressive control may be used to alleviating large outbreaks. Control methods will be determined through a separate environmental analysis. These decisions have the potential to reduce pest losses in the long term. (ROD 23)

c. Monitoring- Ensure that pests do not increase to potentially damaging levels following management activities [36 CFR 219.12(k)(5)(iv)]. (R0D 30)

MAL

a. Intensify timber management activities (using regeneration systems-ROD 29) where severe pest damage has resulted. (ROD 4)

b. Malheur HEI standards lower than Umatilla standards to allow treatments of stands damaged by epidemic pest outbreaks. (R0D 12)

c. Salvaging of mortality will affect ASQ in the next 10 years (ROD 20)

d. ASQ will need to be recalculated following 1992 managed stand survey. Pests and fires have probably reduced that growing stock such that the ASQ will then need significantly reduced. (ROD 22)

e. Large scale pest epidemics have affected most resources. Under the Plan, IPM techniques will be used in a cost-effective manner through vegetative management activities that will result in lower pest losses and and increase in forest health. (ROD-24)

f. Monitoring- Ensure that pests do not increase to potentially damaging levels following management activities [36 CFR 219.12(k)(5)(iv)]. (R0D 35)

Forest-wide Standards and Guidelines (UMA)

a. Selected silvicultural method(s) must promote a stand structure and species composition which minimize risks from pests and fire. (FP 4-67)

b. Silvicultural Rx must address IPM in both the long and short term; use of Rx fire as a silvicultural tool in support of returning fire to its natural role in the ecosystem. (FP4-69)

c. Reforestation- diseased areas will be planted with resistant species favored. (FP 4-70)

d. Precommercial thinning- recommended when stocking level control is needed to protect stands from pests; or thinning needed to protect stands from pests with average diameter larger than 6 inches. (FP 4-71)

e. Management of advanced regeneration- acceptable when residuals free of major diseases.....and will remain free of diseases until rotation age. (FP 4-71)

f. Appropriate stand and site conditions for natural regeneration- there should be no diseased seed trees unless they can be removed before (susceptible) regeneration reaches 2 feet tall/10 years old.

g. Species preference- preference should be given to the healthiest and fastest growing trees, with these objectives being considered through rotation. (FP 4-72)

h. In N and S Associated Working Groups, strong consideration should be given to maintaining stand dominance by seral species rather than pest-susceptible true firs, and to a lesser degree, Douglas-fir. Desirable individuals of shade tolerant species will be maintained in stands to meet diversity objectives. (FP 4-73)

i. Regeneration harvest unit size will be a maximum of 40 acres. Exceptions can increase this up to 60 acres when natural catastrophic situations of fires, blowdown, or pest damage occur. (FP 4-73)

j. Uneven-aged management is most applicable in pure ponderosa pine stands and in Douglas-fir climax communities in stands free of Douglas-fir dwarf mistletoe. In Associated and Lodgepole Working Groups unevenaged management should use group selection techniques, and be done to assure resulting dominance of seral, disease-free species (FP 4-74)

k. Extreme care should be exercised in applying uneven-aged management in stands being impacted by mistletoes, heart rots, and root diseases. (FP 4-76)

Forest-wide Standards and Guidelines (MAL)

a. Maintain best possible HEI in big game summer range when minimum standards cannot be met due to insect/disease conditions, or past management activities. (FP 4-27)

b. Site-specific project analysis will address both short-term and long-term effects, particularly in the case of cover where short-term options to treat stands for pests will improve forest health in the long term. (FP 4-27)

c. Regeneration harvest unit size will be a maximum of 40 acres. Exceptions can increase this up to 60 acres when natural catastrophic situations of fires, blowdown, or pest damage occur. (FP 4-36)

d. stands scheduled for harvest using even-aged management will be managed on rotations which are equal or greater than 95 percent of culmination of MAI- cubic foot measure, unless stand is in imminent danger of pest attack. (FP 4-37)

e. harvest is prohibited on lands unsuitable for timber production unless needed for control of pest outbreaks that threaten land suitable for timber management on non-National Forest lands, or removal of volume lost from catastrophic mortality. (FP 4-38)

f. Reforestation- favor high quality natural regeneration, consider all methods and prescribe the best site-specific method. Manage to maintain or re-establish ponderosa pine, at time of regeneration, on sites where pine is subclimax.

g. Thinning- schedule and implement precommercial thinning to achieve desired stocking level based on a site-specific silvicultural examination and interdisciplinary Rx. Delay or modify thinnings when needed to meet elk habitat objectives; base on site-specific environmental analysis. (FP 4-38)

Forest-wide Standards and Guidelines (WAW)

3. Select silvicultural systems which will, to the extent possible and within the intent of the land management objectives:

    e. Promote a stand structure and species composition that minimizes serious risk of damage caused by mammals, insects, disease, or wildfire, and will allow treatment of existing insect, disease, or fuel conditions. (FP 4-48 & 49)

6. Limit forest openings created by the application of even-aged harvest methods to a maximum size of 40 acres. Exceptions are permitted for natural catastrophic events (such as fires, windstorms, or insect and disease attacks) or on an individual basis after a 60-day public notice period and review by the Regional Forester. In addition, the limits may be exceeded by as much as 50 percent without necessitating review by the Regional Forester or 60 days public notice when exceeding the limit will produce a more desirable combination of net public benefits and when any one of the following four criteria is met:

    b. When created openings cannot be centered around groups of trees infected with dwarf mistletoe or root rot and therefore need to be expanded to include these trees in order to avoid infection of susceptible adjacent conifers. (FP 4-49)

16. Harvest on Unsuited Lands. Permit commercial timber harvest on lands identified as technically unsuited or unproductive (within management areas where harvest is not precluded) only for the following purposes:

    a. Salvage or sanitation harvesting of trees or stands substantially damaged by fire, windthrow, or other catastrophe or which are in imminent danger from insect or disease attack.

    b. Cutting of individual trees or stands to test logging systems, to conduct experiments, or for the purpose of gathering information about tree growth, insect or disease organisms, or the effect of such harvesting on other resources.

c. Cutting of trees to promote the safety of Forest users. This includes hazard tree removal in camp and picnic grounds, in administrative sites, and along roads open to the public. (FP 4-51)

19. Harvest of Catastrophic Mortality. In cases of catastrophic timber mortality such as from fire, insect epidemic, or windthrow, efforts will be made to salvage the affected timber as quickly as possible within the objectives of the affected management areas. (FP 4-51)

Miscellaneous (WAW)

1. Catastrophes. Catastrophes, such as those caused by insect epidemics, fire, floods or weather disturbances will not change the land allocation. The intent is still to achieve the conditions described for the management area. A catastrophe may result in the need for different methods or alter the time frame for achieving the objectives, but the objectives remain the same.

2. Tree Encroachment. Recognize natural grasslands and meadows primarily for the forage value and habitat they provide. Encroachment of trees on meadows and other high forage producing nontimbered sites may be prevented if such action is warranted based on site specific analysis including consideration of other resource objectives.

Wildlife and Riparian

Big Game Winter Range C3 and C3A (UMA)
Wildlife Habitat C4 (UMA)
Riparian C5 (UMA)
Non-Anadromous Riparian Areas 3A (MAL)
Anadromous Riparian Areas 3B (MAL)
Big Game Winter Range Maintenance 4A (MAL)

UMA C3, C3A, C4 - Use IPM principles and strategies in managing pests to meet management objectives. Monitoring and detection of pest conditions and populations will be done so that corrective treatments, consistent with resource objectives, can be prescribed early.

Consistent with resource objectives, protect forest stands (habitats) by practicing prevention activities. Emphasis will be on the the prevention of stand and fuels conditions that favor pests increases above epidemic levels. Aggressively suppress pests using cost efficient strategies when outbreaks threaten resource objectives. (FP 4-154, 157,162)

UMA C5 - Use IPM principles and strategies in managing pests to meet management objectives. Monitoring and detection of pest conditions and populations will be done so that corrective treatments, consistent with resource objectives, can be prescribed early.

Consistent with resource objectives, protect forest stands (habitats) by practicing prevention activities. Emphasis will be on the the prevention of stand and fuels conditions that favor pests increases above epidemic levels. Aggressively suppress pests using cost efficient strategies when outbreaks threaten resource objectives.

The use of pesticides must not conflict with riparian, fish, and water management objectives. (FP 4-170)

MAL 3A, 3B - Apply IPM principles to minimize losses and protect riparian area values. (FP 4-61,68)

WAW Forest-wide Standards and Guidelines-Watershed (Riparian)- not mentioned

WAW Forest-wide Standards and Guidelines-Wildlife- Snag management- Exceptions to guidelines - Areas where catastrophic mortality precludes the leaving of replacement trees, *and*, areas where harvest to treat pest problem (mistletoes, root disease) and leaving of green replacement trees would significantly reduce the effectiveness of treatment. (FP- 4-45)

Record of Decision

WAW

a. At least 30 percent of the forested area within a project be retained as satisfactory or marginal cover at all times; in sale planning, attempt to achieve a HEI of 0.5. Do not reduce timber sale volume to achieve. (ROD 11 - 12)

b. A buffer 100 feet on either side of Class I and II streams will be excluded from *scheduled* timber harvest; exceptions not mentioned.

UMA

a. Except for E1 (Timber and Forage), minimum total cover requirement is 30 percent in forested sites. HEI level of 0.3 to 0.6 (see ROD 10)

b. Effects of pests, fire, past harvest, may make meeting elk habitat requirements and timber harvest objectives difficult. Short-term reductions in cover may be allowed to meet long-term objectives. This will be done through project analysis. (ROD 11)

MAL

a. In riparian areas, non-scheduled harvest will be allowed to accomplish specific riparian resource objectives.

b. Severe levels of recent pest-caused damage will make implementation of satisfactory cover standards in some winter ranges difficult/impossible. Satisfactory cover and total cover standards are thus reduced in large areas (see ROD 12)

Forest-wide Standards and Guidelines (UMA)

a. No mention

Forest-wide Standards and Guidelines (MAL)

a. Marking guides for green replacement trees will be developed jointly by a silviculturist and wildlife biologist to minimize conflicts. Dwarf mistletoes or other pest-infected trees may be retained if they do not pose a significant hazard to the residual stand.

Forest-wide Standard and Guidelines- Wildlife (WAW)

7. Snag Management. Maintain at least the 20 percent level (the management requirement level) of snags 10 to 20 inches in diameter wherever higher levels are not specified and where doing so would not conflict with the primary management area objective. Exceptions include:

   d. Areas where catastrophic mortality such as from fire, disease, or insect epidemic precludes the leaving of green replacement trees.

   e. Areas where harvest is occurring to treat an insect or disease situation (such as dwarf mistletoe or root rot) and leaving green replacement trees would significantly reduce the effectiveness of the treatment. (FP 4-45)

13. Dead and Down Material. Provide dead and down woody material to meet habitat requirements for those species of wildlife, insects, fungi, and other microscopic plant and animal species associated with this type of habitat. Actions to provide this habitat may include such things as leaving one or more concentrations of slash per acre for small mammals and ground-nesting birds, leaving unmerchantable logs on-site in various stages of decay, and activities needed to protect this debris to prescribed fire and fuelwood cutting. (FP 4-46)

Old Growth

Management Area 15 (WAW)
Dedicated Old Growth C1 (UMA)
Managed Old Growth C2 (UMA)
Old Growth 13 (MAL)

WAW 15 - Control of pests is encouraged where pests threaten destruction of an OG stand. Where destruction of the old-growth is not likely, artificial control of pests will occur only when this can be accomplished without adverse effects on old-growth values. (FP 4-91)

UMA C1 - Monitor the levels and activities of pests normally associated with old growth ecosystems. Effects of endemic levels will be accepted as naturally occurring phenomena. No special management practices will be utilized to control losses from insects or diseases at endemic levels.

Suppress or control pests when outbreaks reach epidemic levels and threaten catastrophic loss of dedicated old growth resources or other resources on adjacent lands. Favor biological treatment methods or prescribed burning. IPM methods will not conflict with wildlife objectives. (FP 4-146)

UMA C2 - Use IPM principles to meet management area objectives. Emphasis will be on the prevention of stands and fuel conditions that increase pest populations above epidemic levels. Natural or endemic levels are acceptable and no special management practices will be employed to control losses from pests at these levels. (FP 4-150)

Suppress or control pests when outbreaks threaten managed old growth resources, the ability of stands to become old growth, or other resources on adjacent lands. Favor biological methods when acceptable. IPM methods will not conflict with wildlife objectives. (FP 4-150)

MAL 13 - Allow endemic levels of infestations to occur. Favor biological methods of control is at an epidemic level. (FP 4-107)

Record of Decision

WAW

a. Within two years RF will determine whether changes in OG management measures are necessary. (ROD 17)
b. Catastrophic losses by pests causing loss of OG values not mentioned.

UMA

a. Insect infestations, fire, other catastrophic events will continue to impact this resource (OG) (ROD 18)

MAL

a. Recent wildfires and insect and disease epidemics over the past decade illustrate how easily old growth stands can be lost...we have prescribed an additional 9,600 acres be managed as dedicated old growth (for this reason) (ROD 24)

Forest-Wide Standards and Guidelines (UMA)

a. No mention

Viewsheds

Viewshed 1- A3 (UMA)
Viewshed 2- A4 (UMA)
Visual Corridors 14 (MAL)

UMA A3 - Use IPM principles and strategies to manage pests in meeting viewshed objectives. All treatment strategies may be utilized. Emphasize strategies that improve visual quality, aesthetics, and safety. Treatment of bark beetles and root diseases is emphasized.

Suppress pests when outbreaks threaten users and/or managed resources. Use suppression methods that minimize site disturbance. (FP 4-104)

UMA A4 - Same as Management Area A3

MAL 14 - No harvests will occur in foregrounds of Sensitivity Level 1 or 2 corridors until corridor plans have been completed. Exceptions include pest conditions and sanitation salvage needs on case by case basis; visuals will be the driving factor in decision making. (FP 4-109)

WAW Standards and Guidelines - pests not discussed

Wilderness and Backcountry

Management Area 4 (WAW)
Management Area 6 (WAW)
Strawberry and Monument Rock Wilderness 6A and 6B (MAL)
Wilderness B1 (UMA)

WAW 4 - Monitor the levels and activities of pests normally associated with wilderness and oldgrowth ecosystems. Most pests do not normally pose threats to adjacent lands; effects of endemic levels will be accepted as naturally-occurring phenomena

Suppression activities for pest outbreaks may be permitted with approval (FS-Chief) to prevent loss within wilderness and/or unacceptable resource damage to resources in adjacent areas. Favor available biological methods; follow direction in FSM 2324.1 (FP 4-65)

WAW 6 - Pests outbreaks affecting trees will not be artificially controlled unless it is necessary to protect resources in adjacent management areas. Noxious weeds will be controlled where cost effective. (FP 4-70)

MAL 6A and 6B - Allow endemic levels of infestations. Treat epidemic levels that severely threaten adjacent lands. (FP 4-78,87)

UMA B1 - Monitor the levels and activities of pests normally associated with wilderness and old growth ecosystems. Most pests do not pose threats to adjacent lands; effects of endemic levels will be accepted as naturally-occurring phenomena.

Suppression activities for pest outbreaks may be permitted with approval (FS-Chief) to prevent loss within wilderness and/or unacceptable resource damage to resources in adjacent areas. Favor available biological methods; follow direction in FSM 2324.1. (FP 4-143)

Insects and Disease (Pests)

Forest-wide Standards and Guidelines (UMA)

a. IPM, prevention, and suppression strategies will be utilized to manage pests within the constraints of laws and regulations and to meet Forest-wide management objectives. Methods may include management practices (cultural,silvicultural); biological, mechanical, manual, Rx fire, or chemical treatments; or regulatory measures.

b. All pest management suppression project proposals will be analyzed through the NEPA process to select an appropriate suppression response.

c. Where practical, noxious weeds and invader plants will be controlled to prevent threats to adjacent agricultural lands or to prevent unacceptable loss of forest and range productivity.

Forest-wide Standards and Guidelines (WAW)

Goal

Control Forest pests to levels that are compatible with resource objectives.

Standards and Guidelines

1. Integrated Pest Management. Use Integrated Pest Management (IPM) strategies for early detection, suppression and prevention of Forest pests and to manage pests within the constraints of laws and regulations. IPM strategies include manual, mechanical, cultural, biological, chemical, prescribed fire, and regulatory means. Strategy selection will be based on environmental analysis.

2. Control of Noxious Weeds. Aggressively pursue control of identified noxious weeds on lands where such activities are not precluded by management area direction. This will be accomplished through Forest activities and through coordination with county, State and other Federal agencies as funds permit.

3. When the need to control noxious weeds or competing vegetation is identified, the selection of any particular treatment method will be made at the project level based on a site-specific analysis of the relative effectiveness, environmental effects (including human health), and costs of the feasible alternatives. Herbicides will be selected only if their use is essential to meet management objectives.

4. Cooperate with the Animal and Plant Health Inspection Service (APHIS) in accord with the Memorandum of Understanding between APHIS and the USDA Forest Service.

5. Monitoring. Develop monitoring and enforcement plans for site-specific projects as described in the environmental analysis for these projects. (FP 4-55)

Forest-wide Standards and Guidelines (MAL)

a. Apply integrated pest management principles to minimize the impacts of the mountain pine beetle, western spruce budworm, tussock moth, and other insect and disease infestations to the extent necessary to achieve the overall goals and objectives of this Forest Plan. (FP 4-45)

Watershed, (including Riparian Ecosystems, Streamside Management Units, Floodplains, Wetlands, Water Rights, and Fish Habitat)

Forest-wide Standards and Guidelines (WAW)

13. Groundwater

a. All projects or activities (including but not limited to pesticide application, fertilizer application, or storage of potentially hazardous volumes of fuels and other chemicals on National Forest System land) with the potential to adversely affect surface or ground waters, will include constraints and/or mitigation measures designed to prevent contamination, and will include a plan for dealing with accidental spills. (FP 4-24)

Municipal Watersheds

4. Use of Chemicals. Use of fertilizers and pesticides (chemical or biological) within the watersheds only in emergency situations, and then only following close coordination with the City. (FP 4-26)

Recreation

Forest-wide Standards and Guidelines (WAW)

4. Meet the goals for setting and experience opportunities for each ROS class as outlined below.

Semiprimitive Nonmotorized: Unscheduled timber harvest may occur for salvage of dead timber resulting from catastrophic events or to improve and maintain a healthy, attractive, semiprimitive setting. No new roads...(FP 4-39)

Semiprimitive Motorized: Vegetation management may range from no timber harvest to limited unscheduled regeneration cutting and sanitation salvage for the purpose of maintaining a healthy, attractive semiprimitive setting. Harvest units must meet "foreground partial retention" visual quality objectives. (FP 4-39)

Cave Management

Forest-wide Standards and Guidelines (WAW)

9. Management activities will not be permitted within any area draining into a cave if they are likely to affect the cave ecosystem through sedimentation, soil sterilization, the addition of nutrients or other chemicals (including pesticides, herbicides, and fertilizers) or through change the cave's natural hydrology. (FP 4-47)

Miscellaneous

Forest-wide Standards and Guidelines (WAW)

1. Catastrophes. Catastrophes, such as those caused by insect epidemics, fire, floods or weather disturbances will not change the land allocation. The intent is still to achieve the conditions described for the management area. A catastrophe may result in the need for different methods or alter the time frame for achieving the objectives, but the objectives remain the same. (FP 4-56)

APPENDIX B

PINE RANGER DISTRICT FOREST HEALTH IMPEMENTATION PLAN

FOREST HEALTH THROUGH SILVICULTURE
AND INTEGRATED PEST MANAGEMENT

DRAFT REPORT

OBJECTIVES AND ACTION PLAN

Introduction: On April 9-10, 1990 the Blue Mountain Pest Management Zone (BMZ) and Pine District met to discuss forest health, develop objectives and prepare an action plan that would address issues relating to forest health and integrated pest management opportunities.

Eight major issues were highlighted and objective statements developed that will help direct integrated pest management actions in the future.

Issue 1 - Planning
Objective Statement: Integrate pest management concerns into District's short term project and long term resource management plans.

Issue 2 - Public Involvement
Objective statement: Provide the public an opportunity to be informed about integrated pest management strategies so they can provide knowledgeable input to District plans.

Issue 3 - Resource Management
Objective Statement: Pest management strategies will be a component of all management activities effecting vegetation.

Issue 4 - Pest Prevention and Suppression
Objective Statement: Pest prevention will be built into all District range and silviculture plans and, where the need is recognized, direct suppression of pests will be considered after analyzing the full range of IPM Strategies.

Issue 5 - Environmental Analysis
Objective Statement: IPM will be a part of each environmental analysis where vegetation management is part of the activity.

Issue 6 - Pesticides
Objective Statement: The use of chemical pesticides will be considered along with other IPM strategies for any needed suppression activities consistant with the R-6 vegetative management EIS direction

Issue 7 - Pest Control Technology
Objective Statement: Explore the usual and appropriate new pest management technologies that can be incorporated into the District's vegetation management activities to help improve forest health.

Issue 8 - Forest Health Monitoring
Objective Statement: Indicators of forest health will be monitored in District management activities to assure management goals are being achieved. (Note: until more specific indicators are developed the

desired state of forest health is where the influences of insects, disease, atmospheric deposition, silvicultural treatments, and harvest practices do not threaten management objectives for a given area either now or in the future).

LIST OF FOREST HEALTH RELATED CONCERNS AND THEIR RELATED ISSUES
(a brainstorm list of concerns and issues)

-Annosus root disease, issues 3, 6
-Partial cutting, issues 3, 1
-Bark beetles (all), issues 3, 1
-Old Growth allocation and health, issues 1, 2, 3, 4, 5, 8
-Mistletoe infections in understory and overstory, issues 1, 2, 3, 4, 5, 8
-Long term thermal cover and maintenance, issues 1, 2, 3, 5, 8
-Risk ratings of stands, issues 1, 2, 3, 5, 8
-Multiple pest interactions (species, insects, droughts, etc.) issues 1,3,8
-Drought, issues 8, 2, 3
-Root disease identification and treatment, issues 1, 3
-Slash treatment, issues 2, 3
-Ground based logging, issues 8, 7
-Stocking control, issues 1, 2, 3, 7, 8
-Uneven-age management, issues 1, 2, 3, 5, 4, 8, 7
-Seed orchards, issues 1, 3, 4, 6, 8
-Prescribed fire, issues 1, 2, 3, 8
-Timing of logging and slash treatment, issues 2, 3, 1
-Monitoring forest health, issues 8, 1
-Pest suppression, issues 6, 1, 4, 2, 3, 5, 7, 8
-Tussock Moth, etc., issues 1, 3, 4, 8, 5, 2, 7, 6
-Endemic insect population, issue 8
-Mapping, issue 1, 8
-Wounding, mechanical injury, issues 3, 7
-EA's/EIS, etc., issues 1, 3, 5, 2
-Biological Evaluation, issues 1, 3, 7
-Best use of models (several now available), issues 7, 3, 1, 8
-A check list (user list to help identify problems) issues 1, 3, 7
-Needle Blights/Casts, issues 2, 3, 7
-Training needs, identification, educating of agency, public, issues 1, 2
-Blue Mountain Research Institute, issue 8
-Long term site productivity (new perspectives in Forestry), issue 8
-Apply GIS technology, issues 4, 3, BMZ to add product output

SPECIFIC ACTION REQUIRED:

Issue 1 - Planning (Vegetation Management)

Action	Who	When
1. On 1 or 2 sales involve Craig and Don in doing a Biological Evaluation including time on selected sales ID Teams. (forest health evaluations). A. Dave to identify specific sales.	Don Craig	FY91

2. District to identify pest management zone needs for FY91 (time or projects for specialists). — Dave, Don, Craig — 4/9&10

3. Each EA or project analysis will address pests and IPM needs. — District — FY90
   A. Develop severity index for stand (a future GIS output) - risk rating.
      1. Stand density index
      2. Incidence of disease
      3. Insect activity
      4. Stand age
      5. Species
      6. Aerial survey map

   B. Develop strategy for treatment, alternative development — District — FY90
      1. Use bench mark prescription where appropriate

4. Schedule BMZ for campground evaluations. — Don, Craig, Polly — FY91
   A. Vegetation management planning in campground

5. Develop pest management plans for seed orchards and evaluation plantations. — BMZ & District — FY90/91

Issue 2 - Public Involvement

Action

1. Schedule public/agency field trip to increase understanding and reasoning process (Resource people, public, 2 silviculturists, Ranger) — BMZ & District — May 91
   A. Invite media - news article Record Courier/ Hells Canyon Journal
   B. Paul Joseph - State

2. Handouts: Existing publication on health issues and treatments - share with public and Consensus Group. — District — 7/1/90
   A. Prepare a handout that covers basics: Stocking control, etc.

3. Invite a public representative on one of the sales where pests are a major concern - media, etc. BMZ to attend where appropriate. — District, BMZ — FY91

4. Carry pest related handouts and share with public where appropriate. (State, county) — District — FY90/91 — Dave to check with State

5. Invite key members on recon trips to share info on 1:1 basis. — District — Continuing

6. Slide program of pests and IPM strategies 30 minute slides and discussion when BMZ and specialists are in area. Tussock moth studies, fertilization studies. Try to schedule this summer during one of their visits.	Coord w/ state, FS Don to check with Wickman	maybe this summer and FY91

Issue 3 - Resource Management

Action

1. Design a field trip for agency folks to discuss issues, prescriptions, IPM strategies. Stress identification. Audience target: Field crews, Silviculture, presale, TSE	BMZ/ District	May 3, 1990
2. Risk-rate all activity areas for pest outbreak. Sales, Campgrounds, District - Inventories, stand level, silvicultural tools. BMZ - Biological evaluations (at least 2 sales, I&DC evaluations) Research - Future needs, models, develop mountain pine beetle in ponderosa pine model - need PROGNOSIS variants - better, INFORMS (LaGrande) Pine to keep updated. A. Develop appropriate silvicultural prescriptions that incorporate IPM techniques.	District BMZ/PNW	Now FY91 On going
3. Utilize applicable pest model extensions to PROGNOSIS to evaluate impact of pests on various management options.		

Issue 4 - Pest Prevention and Suppression

Action

1. Prescription should generally result in less than 30% of the tree species in a stand in Budworm host species (i.e. DF, GF in mixed conifer) A. Maintain stocking control through thinning, planting and selected harvest method	District Rx	New sales
2. Stands with substantial root disease will be given treatment priority and converted to a less susceptible condition by species conversion. Stands will not be made susceptible as a result of any activity. A. Control action will be prescribed as appropriate.	District Rx	New sales
3. Stands with Dwarf Mistletoe infestation will be treated to reduce occurrence and severity. Infested stands will be given treatment priority	District Rx	New sales

based on infection severity and understory condition.

4. Direct suppression of certain pests (eg. DFTM) requires prompt District/Forest action to prevent catastrophic losses to resources. Annual monitoring with pheromone traps and lower crown beating will be used to provide advanced warning or to forecast outbreaks. An Environmental Analysis will be scheduled when appropriate to provide adequate lead time to implement a suppression project.	FPM/SO BMZ/Dist.	Continue Monitor
5. Request funding for suppression and presuppression actions with FY financial requests.	BMZ/Dist.	April/May Yearly
6. Where appropriate, reintroduce fire back into the ecosystem to manage competing shade tolerant vegetation. As a pest prevention strategy, the use of periodic prescribed understory burns will be considered as a means of mimicing the role natural fires once played in maintaining seral stands dominated by pest-resistant shade intolerant pines and larch.	District	As prescribed

Issue 5 - Environmental Analysis

Action

1. Environmental and other vegetative management analysis should have a discussion of existing pests and risks and integrated pest management strategies that addresses the pests.	Dist.	On going

Issue 6 - Pesticides

Action

1. District will incorporate state of the art technology in developing treatment recommendations. The use of approved biological or chemical pesticides will be	Dist.	On going
considered along with other IPM strategies.	Dist.	As prescribed

Issue 7 - Pest Control Technology

Action

1. Use of Pheromones to manipulate and control and manage insect populations (emerging technology). Implement after evaluation. (Look at Seed Orchard on going technology.)

2. Use of Borax on F.Annosus (C-provision, C6.412) (look at Torch sale area with Craig).

3. Cultural practice: Species manipulation, damage, prescriptions.

4. Set up demonstration areas: Activities where we are applying IPM techniques.

   A. Spruce stands - beetle intensity, wind-firmness, regeneration, resistance of stands.
   B. Torch sale - root diseases.
   C. Panter - uneven age Rx (photo's, plots, ecotypes)
   D. Thinning - Sparta

Issue 8 - Forest Health Monitoring

Action

1. Monitor the action plan prepared April 9 and 10, 1990. Draft to BMZ by April 27, 1990.	BMZ/Ranger Silv.	On going
2. Develop a district IPM monitoring plan to help determine: parameters, when, who, what, past, results present status, inventory procedures, natural process, artificial treatments.	"	
3. Monitor the effectiveness of pest management Treatment.	"	

* A. Old Growth Management Areas
B. Mistletoe infested understory and overstory
C. Long term thermal cover
* D. Risk rating of stands
E. Multi-pest interactions
F. Drought
G. Ground based logging
* H. Stocking control
* I. Uneven-age management
J. Seed orchard
K. Prescribed fire
L. Pest suppression
M. Tussock moth, etc.
N. Endemic insect populations
O. Use of models
P. Blue Mountain Research Institute
Q. Long-term site productivity (New perspectives in forestry)
R. Checking effectiveness of the harvest prescription (GIS product).

4. Implement GIS technology as available to aid in monitoring forest health. Utilize the following identified GIS pest management products wherever applicable:

A. Identification, distribution, and severity of key pests by forest and by project.
B. Ranking of programmed projects by pest distribution, severity, and volume losses.
C. Ranking of stands by pest distribution and severity.
D. Ranking of stands by pest hazards.

5. Document the results of application of new silvicultural and pest management activities, methods, practices, pilot tests, demonstrations, etc.

revised by Dave Clemens 8/23/90

APPENDIX C

POTENTIAL ECONOMIC IMPACTS

Marc Wiitala, Coop. Forestry, Pacific Northwest Region

Apart from regional and national economic trends and conditions, each of the proposed activities to improve local forest health will have the varying economic and other impacts on local economies. To the extent that the proposed activities go beyond what is prescribed in existing forest plans, the following impacts are likely to be experienced:

-Maintain/protect existing old growth

Timber processing would decline to the degree that existing commercial lands are allocated to nontimber producing old-growth category. Preservation of existing allocation would have little effect on forest industry. Recreation, wildlife, and fishing opportunities in general would rise, thus generating some additional tourism in the area to stimulate seasonal local economic activity.

-Multiple entries (Enhance productivity)

A generally more labor and capital intensive way of managing stands will on net stimulate local economic activities. Management costs will rise requiring a larger forest operating budget. A more aesthetic and less impactful form of management for recreation or preserve fishing opportunities would offer a greater attraction to tourist and fishing. To the extent that tourism rises and fishing increase local economic activity would respond positively. However, this will be offset to some degree by a general loss in wildlife habitat to the degree increased fuels and wildlife risk associated with multiple entries is not offset by a rigorous underburning and fuels treatment program. If associated with an increased fuels treatment and underburning program, seasonal employment would increase markedly, thus bolstering employment and economic activity. Pest suppression project expenditures to deal with the risk posed by periodic sugar pine tortrix outbreaks will produce periodic and ephemeral employment opportunities and spurts of additional local economic activity in service industry.

-Increased uneven-aged management in seral species

A more generally favorable activity for recreation, wildlife, fish habitat, air quality, water quality, and aesthetics will make affected areas more attractive tourist sites. Improved recreation, hunting, and fishing opportunities will, over the long-run, increase economic activity in local service sectors supporting increased tourism and other related activities.

More frequent harvest regime will require more labor and capital inputs than even age management with the possible exception of reforestation work. Local employment will increase as a result. Harvesting cost will rise and stumpage values as a result will decline unless offset by value premiums on larger average harvest diameters. Local PMTS to local governments would therefore decline.

Long-term fire protection needs will increase in these areas. Stands will always contain age classes susceptible to fire effects. Associated larger protection organization will increase both seasonal and permanent employment in the local community. A reduced need for periodic underburning for stocking control will somewhat offset any employment increases, particularly seasonal.

-Trees planted per acre

Local employment will decline as fewer trees planted per acre will require fewer labor inputs to the reforestation process. This will be offset to some degree by the need to replant more frequently as the risk of successful initial artificial regeneration declines. Reduced need for precommercial thinning will also reduce employment opportunities.

Local forest products processing and associated income and employment will decline along with a reduction of timber volumes. Lower volumes may result from lower average stocking levels if they either delay commercial entries or provide less volume in initial entries.

-Increased conversion of stands to seral species

If this activity is in addition to forest plan harvest activities, increased harvesting activity in short-term would increase economic activity in local forest products industry.

Livestock grazing opportunities will rise as will most activities associated with wildlife, fisheries and recreation. The result over the long term will be to increase economic activities in the local service industries supporting greater external and local public participation in these areas. This will be offset to some degree by a short-term aesthetics degradation as attending the initial conversion process. Local economic activity will decline as a result of a reduction in risk of large wildfires and pest outbreaks. This lower risk will reduce the need for expenditures and local employment in presuppression and suppression organizations. Some offset will come via the periodic need for prescribed burning of natural and activity fuels.

-Increased thinning

Increased volume production from commercial thinning will increase economic activity in local forest products industry and supporting service areas in so far as it is not substituted for other volume.

Seasonal employment for commercial and precommercial thinning will rise bolstering local economics. A similar result will be experienced should a need arise for additional activity fuels treatment. Precommercial thinning at relatively early ages would obviate the need for slash treatment.

-Increased seed production ability

Ability to more rapidly convert stands to preferred species that are generally more productive and less susceptible to fires and pestilence will increase substantially long-term volume production. In the long-term the local economy will be bolstered by the availability of additional volume for the wood processing industry. Seed production areas will require additional measures of protection against fire and pests. Provision of this protection will require additional local employment and forest expenditures on things such as fire break instruction and maintenance, increased local initial fire suppression capability, improved fire detection, and period pest suppression efforts. Local economic activity will increase in response.

-Establish old-growth replacement program

There will be some increase of fish and wildlife habitat and recreation use opportunities during transition to old-growth condition. This will lead to an increase in local service industries supporting these activities.

Any increase in total local employment and activity from these activities may be more than offset by the reduction in timber volume and affected economic activities as additional lands are allocated to nontimber or restricted timber producing states.

Employment and expenditures for presuppression and suppression would diminish if areas allocated for commercial forestry are relocated to a growth transition status. Reductions here could be offset to some degree by the need to provide adequate pest protection against periodic pest outbreaks during the transition period. Periodic suppression projects would provide very localized, ephemeral economic stimulus to local economies from time to time.

-Weed control

Minimal local economic impacts.

-Increased natural fuels burning program

Increased burning programs will require higher levels of seasonal spring and fall employment to carry out programs and address increased risk of caped prescribed fires. The local economy will benefit accordingly. This will be offset by reduced need for wildfires presuppression/suppression expenditures and employment.

The reduction in faster-growing, less-valuable fire tolerant species will lower current and future allowable sale quantity. Hence, the wood processing industry will incur lower levels of employment. Loss of total income may eventually be recovered by the longer-term processing, higher-valued fire tolerant species such as larch and ponderosa pine. Fewer larger wildfires and acres burned would also mitigate volume losses.

The livestock industry will be positively affected by improvement in quality of existing grazing habitat and its ability to support livestock numbers. Increased forage production will also be provided for wildlife.

-Enhancing long-term productivity through cable/helicopter logging

Cable and helicopter logging are more capital intensive and expensive than other logging systems commonly used. Local supplies of these services or equipment would benefit at the expense of supplies of tractor/skidder logging equipment. The higher cost of logging would reduce stumpage prices and therefore payments to counties.

Reduced compaction, residual tree damage, and generally increased productivity, as well as increased access to previously inaccessible areas, would make available more timber volume over both the short and long term. Resulting increase in harvesting and processing would lead to sustained increases in local economic activity and employment. Less disturbance of logged areas would be generally beneficial to production of other forest resources. Resultant attraction to tourism, hunting, and fishing would stimulate local employment activity in economic sectors servicing these activities. Reduced road access will make fire suppression in roadless areas more difficult. This in turn could lead to a greater risk of large fires, more annual acres burned, and reduced volume production.

FOREST HEALTH ANALYSIS NEEDS
ECONOMIC AND SOCIAL CONSIDERATIONS

Dale Pekar, Economist, Wallowa-Whitman National Forest

General

During recent historical times the Blue Mountain region of northeastern Oregon and southwestern Washington has experienced a series of insect and disease outbreaks which have killed or stunted large amounts of timber, degraded the overall health of various forest ecosystems, and promoted a visual landscape unappealing to many users. The deleterious effects of these outbreaks have included an increased loss of timber to wildfire. A topical assessment of the situation indicates the need for further analysis as detailed below.

Social

People want to know how any proposed actions might affect them. For some people the primary focus of this interest is economic--as discussed above. For others, the social dimension is more important.

All people in the local area, and many outside it, are affected in their social interactions by Forest management. Decisions made on the Forest affect lifestyles (both at work and at leisure), attitudes, beliefs, and values. Community cohesion can be affected positively, as in those instances in which consensus develops, or negatively, as can happen when parties end up taking sides.

Effects on the area population, poverty, unemployment all have to be considered. Any differential effects on minorities need to be addressed.

Economic

Efficiency Concerns

People are concerned about money. They want to know that their money is being wisely spent. They want to know that their assets, in the form of the National Forests, are being managed wisely and well. An efficiency analysis addresses these concerns. It looks into the costs of correcting problems and compares those costs with the benefits attributable to the work.

This analysis can take many forms. It can be complex or simplistic depending on the amount of detail management needs to make an informed decision. It addresses only those factors under study.

For an investigation into the health of the Blue Mountain Forest ecosystem, one reasonable approach would be to first estimate what would happen if no corrective measures were taken. This would comprise the baseline scenario or alternative against which all action alternatives would be compared.

The dollar-quantified costs and benefits associated with each action alternative would then be compared with those of the "No Corrective Action" alternative. To ensure a complete analysis the costs and benefits would be calculated well into the future--anywhere from 50 to 150 years. Costs and benefits would be defined as they occur over time, discounted to present terms, and compared.

To the extent possible, market values would be used to assign dollar costs and benefits. Where not possible, RPA or other established data sources would be used.

Care would be taken to ensure that the decisionmaker was presented information as accurate as possible given the time and dollar constraints associated with the work. Any analysis of the use of fire would have to include the costs of escaped prescribed burns, for instance. Any discussion of the use of pesticides would have to reflect the extra costs that occur when meteorological conditions change and crews have to delay work. Any dollar-quantified cost or benefit that varies significantly by alternative would be included.

Theoretical models would have to be ground-truthed to the conditions present on the National Forests of the Blue Mountains. Conceptually it might be accurate to state that a certain management regime would yield more forage, for instance. Whether that forage could translate into more forage consumed by domestic livestock (more animal unit months of livestock grazing) would be another question and it would have to be answered within the complete Forest context.

Timber yield tables would likewise have to reflect real world conditions as best as possible rather than laboratory conditions. In all cases, perfect information is not available. The limitations of the data would be stated along with the assumptions used.

Effects on the Local Economies

People want to know how any proposed actions would affect them economically as individuals and as members of groups. They want to know whether their jobs would be affected, whether their take-home pay would be affected, whether their local government services would be affected.

Estimates would be needed for the numbers of jobs (by economic sector), the amount of personal income, and the dollar value of payments to local governments associated with the various alternatives developed.

The linkages between proposed actions and the local economy are not always clear. Whether a change in payments to local governments actually would translate into a change in property taxes, for example, would be open to question. There is little to be gained by doing anything other than acknowledging such linkages. Likewise, there is no sense in trying to estimate effects which are reasonably reckoned to be insignificant--such as the effects on the rates of income taxation--or which would not vary significantly by alternative.

National Forest Budget Effects

Forest managers have to work within a budgetary framework at all times. They are not free to do what they will with the funds available. Managers need to know how proposed actions will affect their budgets. Estimates have to be made as to the effects the various alternatives would have on Forest budget line items.

APPENDIX D

UNEVENAGE MANAGEMENT AND FOREST INSECT AND DISEASE PESTS: A SHORT PERSPECTIVE

Donald J. Goheen FPM, Pacific Northwest Region

The USDA Forest Service will be practicing unevenage management in many Eastside Oregon and Washington stands in the future. There is a clear mandate from the public to do so. If properly done in appropriate locations, unevenage silvicultural systems have the potential to address esthetic, wildlife, and recreation concerns in a superior fashion while producing nearly as much timber as could be produced using evenage systems. However, proper and appropriate use of unevenage silviculture is not easy and will require considerable expertise and skill. It cannot involve any of the "pick and pluck" high-grading of the past. For one thing, a full understanding of the insect and disease implications of implementing unevenage prescriptions will be absolutely essential for the manager. There must be a strong commitment to minimizing pest-caused losses using an integrated approach. Pest management concerns should be major factors in determining where unevenage management will be done and in deciding what kind of unevenage system to use.

Insects and diseases can cause highly significant losses in East Side Oregon and Washington forests. The following is a list of the most damaging pests and the kinds of stands in which their damage is usually greatest:

Pest	Stand Type with Greatest Damage Potential
Mountain Pine Beetle	Overstocked, clumpy ponderosa pine stands (stands with basal areas of 150 square feet or greater per acre measured around any individual tree on better sites--lower on poor sites); stands of low vigor lodgepole pine that are usually overstocked and overmature (80 years old or older).
Western Pine Beetle	Stands containing overmature, low vigor ponderosa pines; also appearing with ever- increasing frequency in the same kinds of overstocked, clumpy ponderosa pine stands commonly damaged by mountain pine beetle.
Dwarf Mistletoes	Multistoried host stands with already- infected over-stories; damaging mistletoes of East Side Pacific Northwest forests include Douglas-fir dwarf mistletoe, larch dwarf mistletoe, western dwarf mistletoe (on ponderosa pine), lodgepole dwarf mistletoes, and, in some cases, true fir dwarf mistletoe; these dwarf mistletoes are quite host specific except larch dwarf mistletoe which can cross readily to lodgepole pine.
Defoliating Insects	Multistoried stands with major true fir and/ or Douglas-fir components; western spruce budworm and Douglas-fir tussock moth are the major insects of concern.

Laminated Root Rot	Stands with major true fir and/or Douglas-fir components where inoculum is present.
Armillaria Root Disease	Differs by area but generally stands with major true fir components; sometimes also favored by factors that stress trees.
Annosus Root Disease	Stands with major true fir components where inoculum is already present or new infection foci can develop as a result of windborne spores colonizing large fir stumps (18" or more in diameter).
Indian Paint Fungus	Stands that contain a major component of true fir and have a history of tree suppression and wounding.
Fir Engraver Beetles	True fir stands with root disease or undiseased stands suffering from drought stress.

Based on this table, it is evident that silviculturists who wish to minimize East Side pest-caused losses much strive to avoid creation of three general stand types: (1) overstocked pine stands; (2) multistoried stands with significant components of dwarf mistletoe hosts and mistletoe infection of that same host in the overstory; and (3) multistoried stands with major Douglas-fir and/or true fir components, a history of suppression and tree wounding, and root diseases present. For the silviculturist who wishes to consider use of unevenage management systems and at the same time minimize pest losses, the following suggestions are made:

(1) From the pest management perspective, the individual tree selection system is most appropriate in ponderosa pine stands without dwarf mistletoe. Stands treated in this way will require stocking control. Stocking levels will need to be considered around each individual tree where trees of many different sizes are to be maintained in the stand. Spacing guidelines will be extremely difficult to prepare, and skilled, experienced markers will be invaluable. Group selection treatments can also be used in these kinds of stands, and stocking control will be easier to implement.

(2) In mistletoe-infected pine stands, group selection cuts may be appropriate. However, it will be *very* important to design boundaries or do follow-up work to avoid reintroduction of mistletoe into the harvested areas. Small-sized treatment areas will require special vigilance.

(3) In mixed conifer types, unevenage management would be best used in stands where seral species can be favored over the more pest-prone Douglas-fir and true firs. Group selection cuts, where pine or larch are reestablished by planting or where larch or pine seed trees are maintained, seem most likely to succeed. In many mixed conifer stands, one or more dwarf mistletoes are likely to be present, and again, boundary design and follow-up treatment of trees surrounding the cut area will be extremely important.

(4) In mixed conifer stands where Douglas-fir and true fir are dominant, seral species do not constitute a significant portion of the stocking, and root diseases are present and widely distributed, evenage silvicultural systems are most appropriate. This is especially true if stands contain many suppressed and/or injured true firs as well.

(5) Silviculturists considering use of unevenage prescriptions but unsure of the pest implications in their individual stands should consult with appropriate zone pest specialists or entomologists or plant pathologists from Forest Pest Management.

APPENDIX E

THE RELATIONSHIP OF FOREST HEALTH TO RECREATION AND VISUAL RESOURCES

Robin Rose, Recreation Specialist
Wallowa-Whitman National Forest

The scenic diversity found in the Blue Mountains contributes greatly to the recreational value of our National Forests and provides the public with unique visual enjoyment. The health of the forest contributes to the overall appearance of the landscape, and thus, potentially affects the recreation and visual resources.

The objective of landscape management is to manage all National Forest System lands so as to attain the highest possible visual quality commensurate with other appropriate public uses, costs, and benefits. In order to comply with the objective, the USDA Forest Service developed the visual management system.[1] Using landscape variety classes, viewer sensitivity levels, and viewer distance zones, visual quality objectives (VQOs) are established to determine the amount of alteration portions of the landscape can sustain without jeopardizing visual quality.

Each landscape has a definable character, and those with the greatest variety or diversity have the greatest potential for high scenic value. Each landscape unit has its individual capacity to accept alterations in color and texture without losing its inherent visual character. Landscapes with a high degree of variety typically have a higher capability to absorb alterations.

Aesthetic concern varies among National Forest users. Those people most concerned about aesthetics are those who are in an area because of, or have a major interest in the scenic qualities, e.g., recreationists, residents, and travelers. The sensitivity level of a landscape increases as the number of recreation-oriented visitors to an area increase.

The majority of the recreation-oriented people who visit the National Forests have an image of what they expect to see. Such an image or mental picture is generated by available information concerning a particular area and the person's experience with that or similar areas. Although studies of people's image of forest areas result in varied responses from one geographic region to another, one factor generally remains constant. People expect to see a naturally-appearing character within each general region.

Visual resources are strongly interwoven with the recreation setting. When lands are managed with emphasis on recreation opportunities, the normal assumption is that users have a high sensitivity for natural to near natural appearing landscapes. The relative appearance of an area is important to the recreation experience an individual may have. A variety of landscapes also helps to provide a diversity of settings for recreation opportunities. Therefore, management of visual resources is generally in concert with recreation objectives, but may affect the physical setting. Generally, unroaded areas, classified areas, viewsheds, recreation sites, and special areas are managed with an emphasis on visual quality. Other areas are managed with less concern about visual quality.

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[1] Forest Service Manual 2380: Landscape Management. U.S. Department of Agriculture.

The Blue Mountains occur entirely within a geographic "province" encompassing a large portion of northeastern Oregon. The Blue Mountains province includes a diversity of landscape types, from highly scenic rugged mountains and canyons with varied vegetative patterns, to moderately scenic rolling terrain with less vegetative variety, to nearly monotonous flat and uniform landscapes. The three National Forests of the Blue Mountains generally present natural to near natural appearing landscapes to visitors.

Climatic and geologic events, insects, diseases, animals, and fire interacted with each other and with vegetation to influence forest development. Among the natural ecological agents, insects and disease rank with fire and climate as having important impacts on the appearance of the forest. Generally speaking, from a visual management perspective, a landscape that has been effected by natural forces is natural appearing and its aesthetic integrity is intact. Under normal endemic conditions, tree mortality is patchy in nature, ultimately creating a mosaic of naturally shaped openings in the canopy, and thus contributing to the mosaic of vegetative patterns. Due to the fact that varying sizes and intensities of impact or mortality are intermingled with green areas, visual variety is introduced to the characteristic landscape. The resulting snags and deformed "character trees" also provide visual interest and variety to the landscape. The effect of endemic levels of insects and disease may be considered negative only in the sense that some management options may be foregone until vegetative screening returns and other natural recovery processes have begun.

Many forest diseases occur throughout the three Blue Mountain forests; however, since disease centers are fairly limited in size, and not always visually evident to the casual observer, the potential impacts on the visual resource are of somewhat less concern that those created by insect outbreaks. Outbreaks of forest insects exceeding normal endemic levels can create dramatic changes in color and texture in the landscape.

Scenery is influenced by the degree to which conifers are defoliated or damaged. Light feeding by defoliators may not even be noticeable to the casual observer. From a visual standpoint, the impact is transient during the early stages of an outbreak. Foliage that has been damaged by insects turns red in the summer as it dries, and is very noticeable. After winter wind and rain storms remove the dead foliage from the trees, many people may not even be aware of the past feeding in an area. Crowns that become thin from repeated foliage loss, later in the outbreak, are very recognizable to the public. To some individuals, heavy feeding such as this creates a visual impact that alters the scenic beauty of the area.

As outbreaks progress, the visual effect of dead and dying timber, if untreated, will occur predominately as contrasts in color (especially in middleground and background) as follows: first, red, as the needles, and then later, grey, as they drop exposing the branches. Some less noticeable changes in texture will also occur in middleground and background as needles drop and only standing poles remain, then only jack-strawed poles. In foreground areas, because more detail is discernible, some slight contrasts in form and line will occur as needles fall, then branches and bark, then jack-strawed poles. The effects described will be most noticeable in large stands of host trees, and will decrease as the stand size decreases and/or the number of trees of other species within the stand increases.

While such outbreaks can enhance variety and diversity, when the effected area becomes dominant and out of scale with other landscape elements, the effects may be perceived by visitors as negative rather than positive. There is also some risk that the combined effects of a large outbreak and those created by past management activities may make it difficult to meet the prescribed visual quality objectives of some visually sensitive viewsheds. The use of preventative measures may be desirable to control the amount of road frontage, key recreation sites, and other visually sensitive areas that would be impacted at one time to minimize the potential for negative impacts. In some cases, rehabilitation may need to be considered as a short term objective to restore portions of the landscape to a desired visual quality.

Salvage efforts often follow these natural events. Removing dead and down timber to supply lumber and chip markets can reduce the potential for catastrophic wildfire. But salvage activities may also reduce visual quality in some instances. In the event salvage becomes necessary, activities should be carefully designed to maintain the natural shapes and edges and remaining screening to aid in the recovery of healthy, natural-appearing forests.

Forest insect outbreaks may influence the recreational use that an area receives. When large numbers of insects are present, or when tree damage becomes significant, the quality of the recreation experience may likewise be affected. Recreation sites in host-type stands may be at risk for substantial tree mortality, presenting great risk of injury to individuals and property. The primary detrimental effects to a recreation site would be the unacceptable level of hazard created by the dead and dying trees, requiring removal of the trees or temporary closure of the site.

Secondary negative effects include the diminished attractiveness of recreation sites, reduced protection from the other elements and psychological discomfort due to a loss of cover and shade. Like other animals, people desire protection from the elements, screening or hiding cover, close proximity to water, natural-appearing edges, and unencumbered flat sites.

Whether forest insect outbreaks adversely affects the visitations of impacted areas by recreationists and hunters, is not known. A study undertaken during the Douglas-fir tussock moth outbreak in northeast Oregon in the early 70's found little evidence that recreation use was impacted at all.[2] In fact, the public exhibits some curiosity in viewing the effects of "natural disasters" on the landscape. While some recreational activities such as sightseeing and camping may be adversely effected in the short term, other recreational activities benefiting from a highly diverse setting may be enhanced, such as mushroom and berry picking, hunting, wildlife viewing, and nature study.

As naturally-occurring events, forest insect and disease influence the ecology of the area and add variety and diversity to the landscape. Providing the public with information on the role of such natural processes in the overall functioning of forest ecosystems will help to promote public understanding and acceptance of these natural phenomenon.

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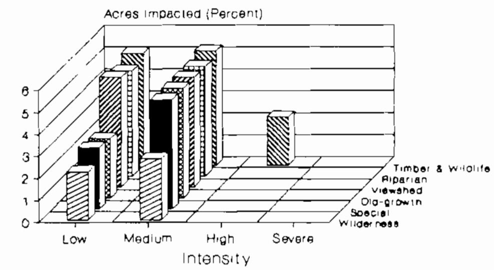
[2] Downing, K.B.; Delucchi, P.B.; Williams, W.R. Impact of the Douglas-fir Tussock Moth on Forest Recreation in the Blue Mountains. Res. Paper PNW-224. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1977.

APPENDIX F

MANAGEMENT ALLOCATIONS IMPACTED BY DISEASES

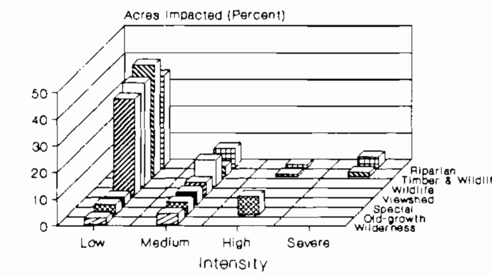
The questionnaire responses from the Ranger Districts of the National Forests in the Blue Moutains include estimates of the proportion of the management allocations currently impacted by forest diseases for all vegetation series.

Proportion of Management Allocation Impacted by Laminated Root Rot at Different Intensities in the Blue Mt.



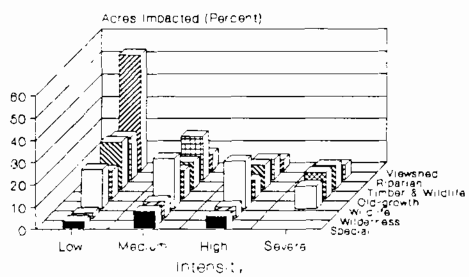
Means from responding Ranger Districts to 1990 Forest Health Questionnaire.

Proportion of Management Allocation Impacted by Armillaria Root Disease at Different Intensities in the Blue Mt.



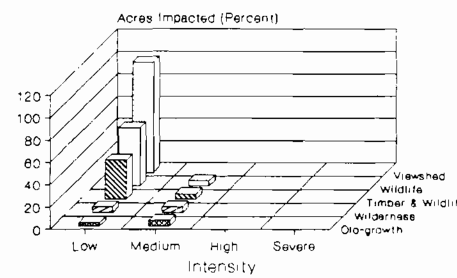
Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Management Allocation Impacted by Annosus Root Disease at Different Intensities in the Blue Mt.



Means from responding Ranger Districts to 1990 Forest Health Questionnaire

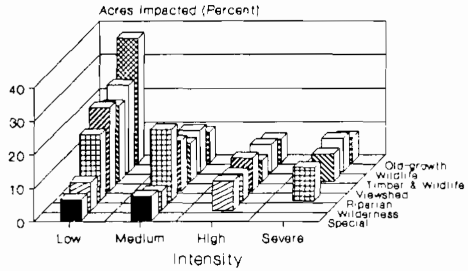
Proportion of Management Allocation Impacted by Black Stain Root Disease at Different Intensities in the Blue Mt.



Means from responding Ranger Districts to 1990 Forest Health Questionnaire

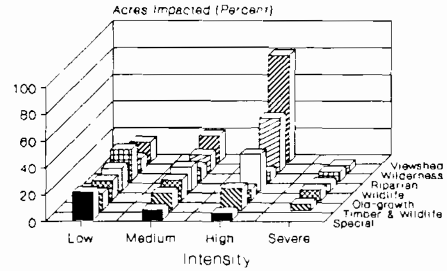
F1 - Management allocations impacted by diseases

Proportion of Management Allocation Impacted by Western Dwarf Mistletoe at Different Intensities in the Blue Mt.



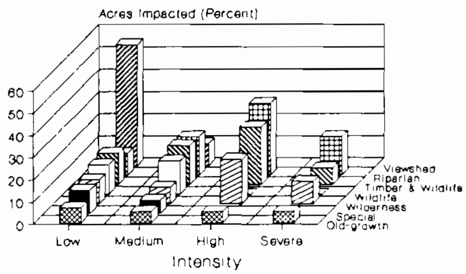
Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Management Allocation Impacted by Douglas-fir Dwarf Mistletoe at Different Intensities in the Blue Mt.



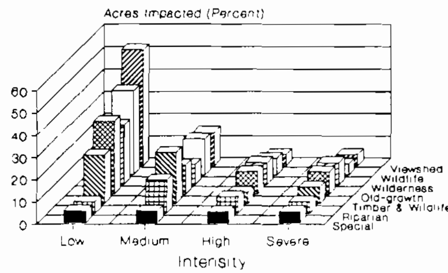
Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Management Allocation Impacted by Lodgepole P. Dwarf Mistletoe at Different Intensities in the Blue Mt.



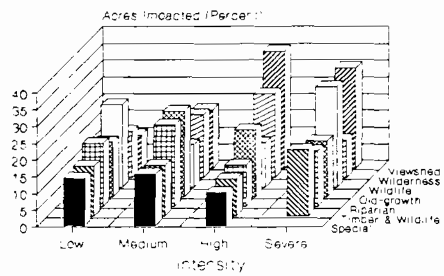
Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Management Allocation Impacted by Larch Dwarf Mistletoe at Different Intensities in the Blue Mt.



Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Management Allocation Impacted by Indian Paint Fungus at Different Intensities in the Blue Mt.

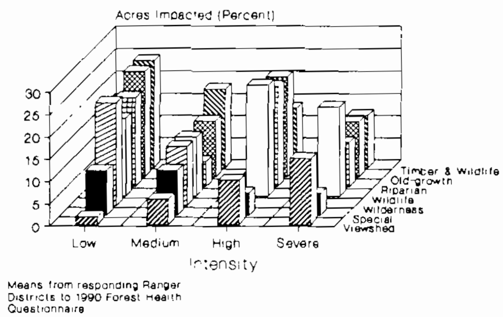


Means from responding Ranger Districts to 1990 Forest Health Questionnaire

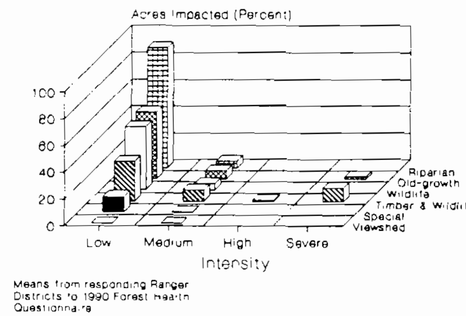
MANAGEMENT ALLOCATIONS IMPACTED BY INSECTS

The questionnaire from the Ranger Districts of the National Forests in the Blue Mountains include estimates of the proportion of management allocations currently impacted by forest insects for all vegetation series.

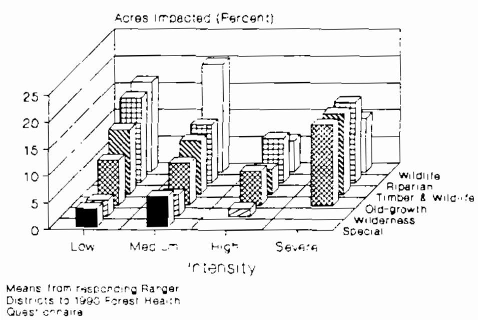
Proportion of Management Allocation Impacted by Western Spruce Budworm at Different Intensities in the Blue Mt.



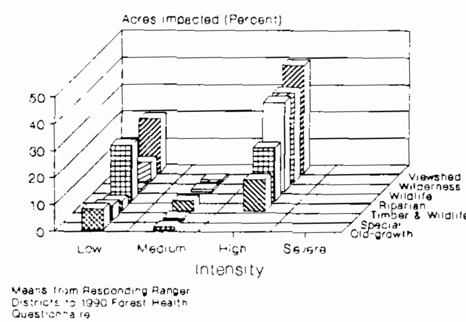
Proportion of Management Allocation Impacted by Douglas-fir Tussock Moth at Different Intensities in the Blue Mt.



Proportion of Management Allocation Impacted by Douglas-fir Beetle at Different Intensities in the Blue Mt.

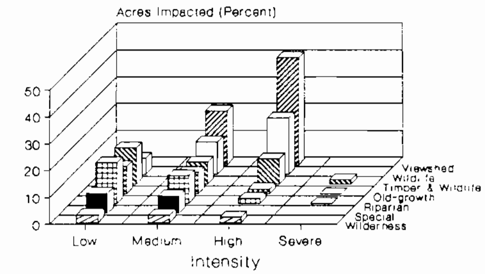


Proportion of Management Allocation Impacted by Mountain Pine Beetle at Different Intensities in the Blue Mt.



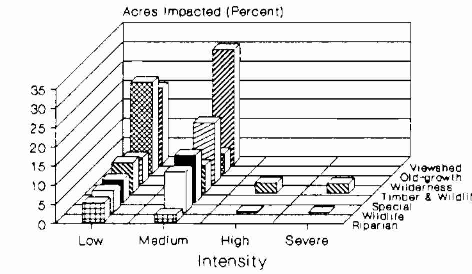
F2 - Management allocations impacted by insects

Proportion of Management Allocation Impacted by Fir Engraver at Different Intensities in the Blue Mt.



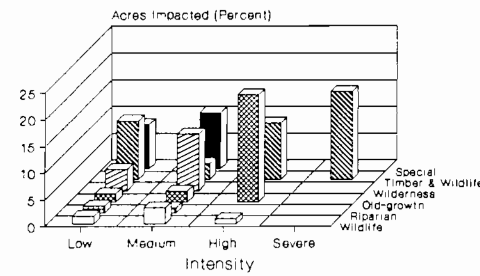
Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Management Allocation Impacted by Western Pine Beetle at Different Intensities in the Blue Mt.



Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Management Allocation Impacted by Spruce Beetle at Different Intensities in the Blue Mt.

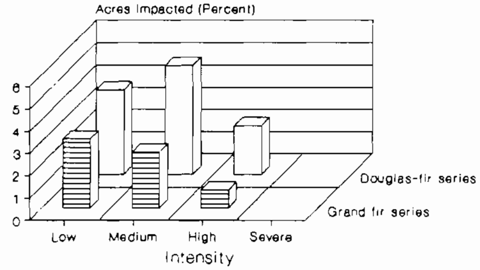


Means from responding Ranger Districts to 1990 Forest Health Questionnaire

VEGETATION SERIES IMPACTED BY DISEASES

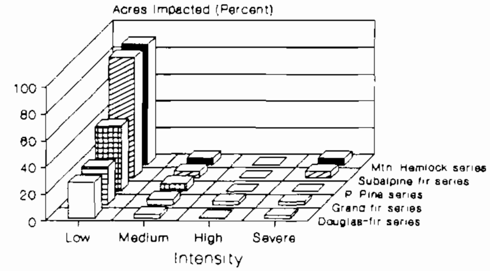
The questionnaire from the Ranger Districts of the National Forests in the Blue Mountains include estimates of the proportions of vegetation series currently impacted by forest diseases for all management allocations.

Proportion of Vegetation Series Impacted by Laminated Root Rot at Different Intensities in the Blue Mt.



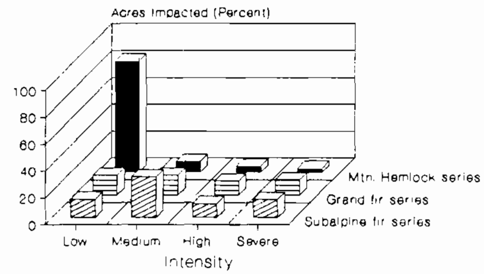
Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Vegetation Series Impacted by Armillaria Root Disease at Different Intensities in the Blue Mt.



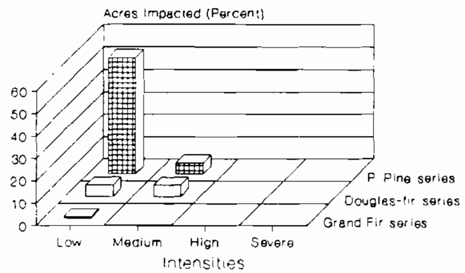
Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Vegetation Series Impacted by Annosus Root Disease at Different Intensities in the Blue Mt.



Means from responding Ranger Districts to 1990 Forest Health Questionnaire

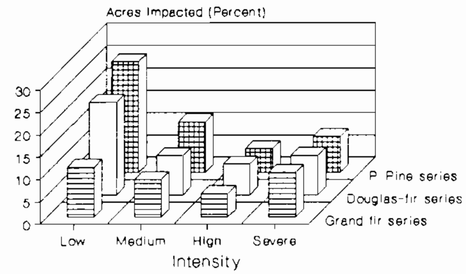
Proportion of Vegetation Series Impacted by Black Stain Root Disease at Different Intensities in the Blue Mt.



Means from responding Ranger Districts to 1990 Forest Health Questionnaire

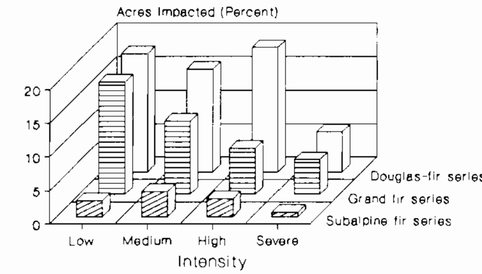
F3 - Vegetative series impacted by diseases

Proportion of Vegetation Series Impacted by Western Dwarf Mistletoe at Different Intensities in the Blue Mt.



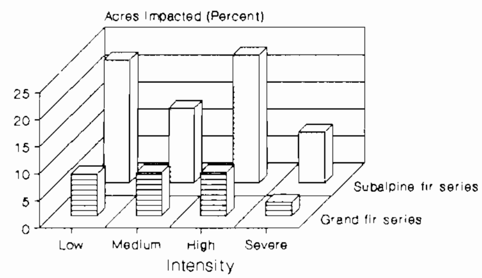
Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Vegetation Series Impacted by Douglas-fir Dwarf Mistletoe at Different Intensities in the Blue Mt.



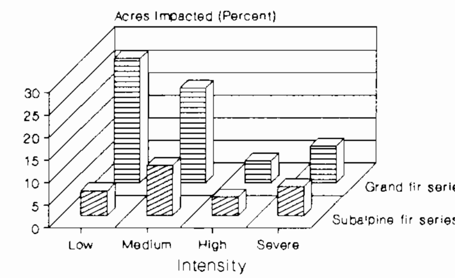
Means from responding Ranger Districts to 1990 Forest Health Questionnaire.

Proportion of Vegetation Series Impacted by Lodgepole Pine Dwarf Mistletoe at Different Intensities in the Blue Mt.



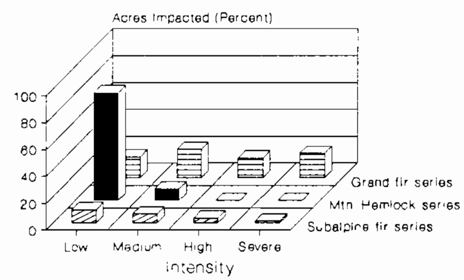
Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Vegetation Series Impacted by Larch Dwarf Mistletoe at Different Intensities in the Blue Mt.



Means from responding Ranger Districts to 1990 Forest Health Questionnaire

Proportion of Vegetation Series Impacted by Indian Paint Fungus at Different Intensities in the Blue Mt.

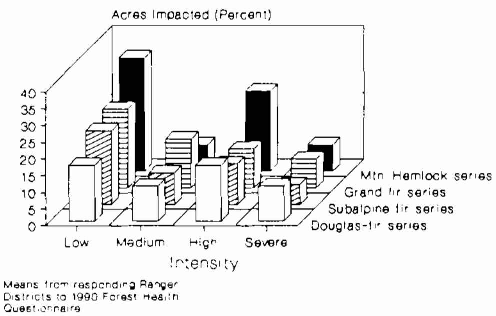


Means from responding Ranger Districts to 1990 Forest Health Questionnaire

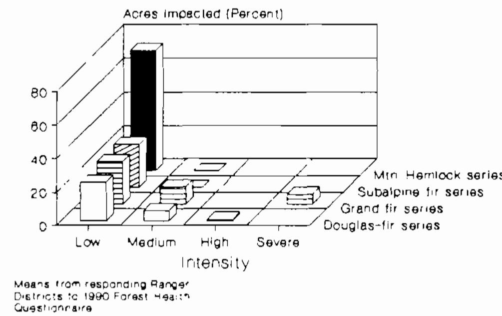
VEGETATION SERIES IMPACTED BY INSECTS

The questionnaire from the Ranger Districts of the National Forests in the Blue Mountains include estimates of the proportion of vegetation series currently impacted by forest insects for all management allocations.

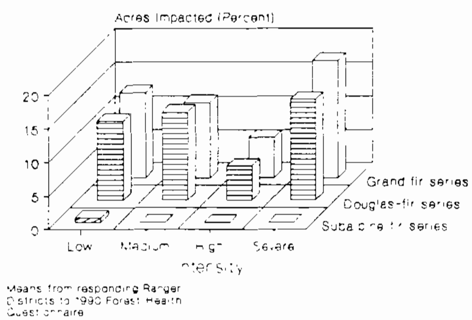
Proportion of Vegetation Series Impacted by Western Spruce Budworm at Different Intensities in the Blue Mt.



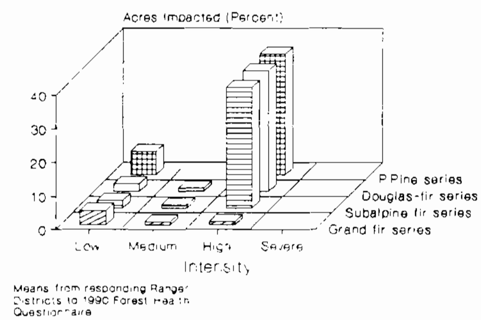
Proportion of Vegetation Series Impacted by Douglas-fir Tussock Moth at Different Intensities in the Blue Mt.



Proportion of Vegetation Series Impacted by Douglas-fir Beetle at Different Intensities in the Blue Mt.

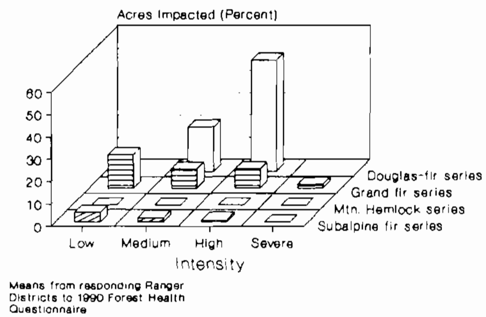


Proportion of Vegetation Series Impacted by Mountain Pine Beetle at Different Intensities in the Blue Mt.

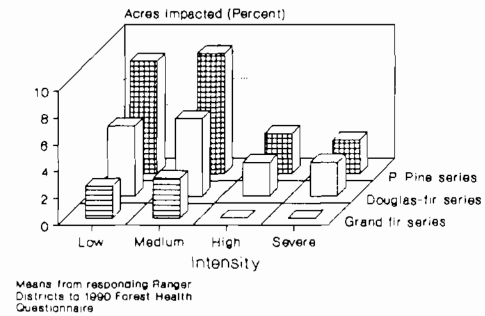


F4 - Vegetative series impacted by insects

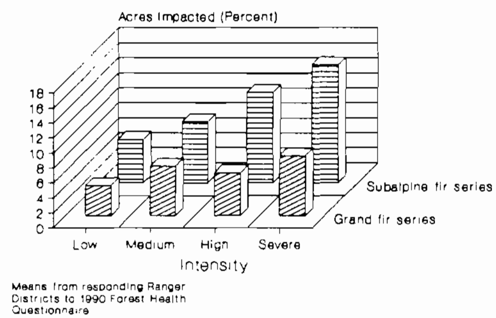
Proportion of Vegetation Series Impacted by Fir Engraver at Different Intensities in the Blue Mt.



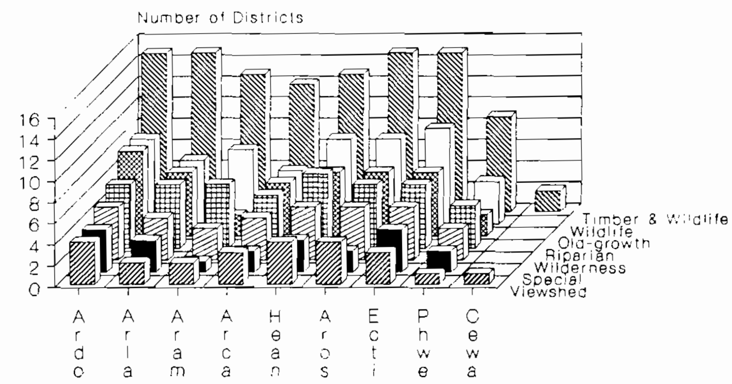
Proportion of Vegetation Series Impacted by Western Pine Beetle at Different Intensities in the Blue Mt.



Proportion of Vegetation Series Impacted by Spruce Beetle at Different Intensities in the Blue Mt.



Number of Districts Identifying Impacts by Specific Diseases by Management Allocation

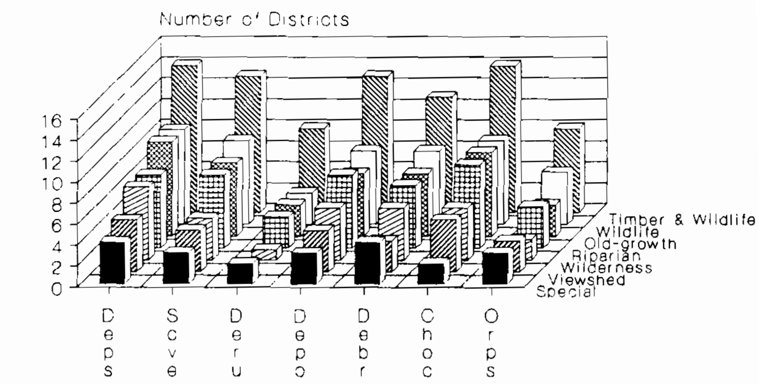


Responses of Ranger Districts to
1990 Forest Health Questionnaire.

Disease Abbreviations

Aram = Lodgepole pine dwarf mistletoe
Arca = Western dwarf mistletoe
Ardo = Douglas-fir dwarf mistletoe
Arla = Larch dwarf mistletoe
Aros = Armillaria root disease
Cewa = Black stain root disease
Ecti = Indian paint fungus
Hean = Annosus root disease
Phwe = Laminated root rot

Number of Districts Identifying Impacts by Specific Insects by Management Allocation



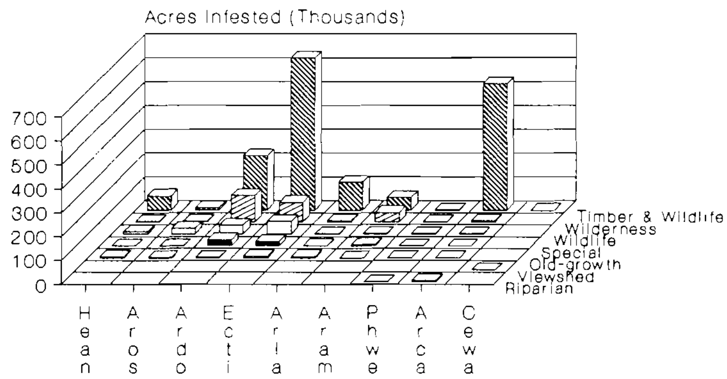
Responses of Ranger Districts to
1990 Forest Health Questionnaire

Insect Abbreviations

Choc = Western spruce budworm
Debr = Western pine beetle
Depo = Mountain pine beetle
Deps = Douglas-fir beetle
Deru = Spruce beetle
Orps = Douglas-fir tussock moth
Scve = Fir engraver

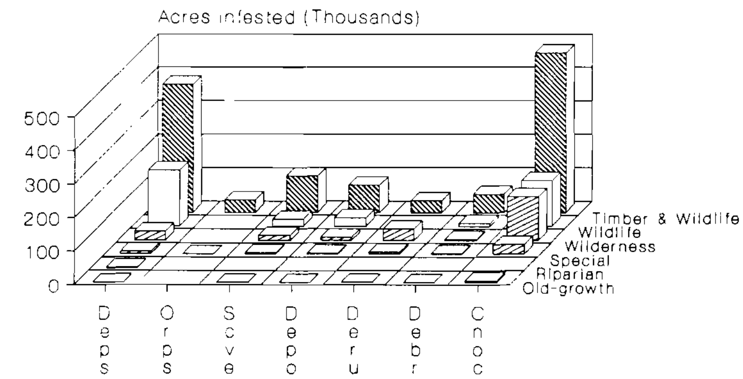
F5 - Number of Districts identifying impacts by specific diseases and insects by management allocation

Area Identified Infected by Specific Diseases of the National Forests in the Blue Mountains



Responses of Ranger Districts to
1990 Forest Health Questionnaire

Area Identified Infested by Specific Insects of the National Forests in the Blue Mountains



Repsonses of Ranger Districts to
1990 Forest Health Questionnaire.

Disease Abbreviations

Aram = Lodgepole pine dwarf mistletoe
Arca = Western dwarf mistletoe
Ardo = Douglas-fir dwarf mistletoe
Arla = Larch dwarf mistletoe
Aros = Armillaria root disease
Cewa = Black stain root disease
Ecti = Indian paint fungus
Hean = Annosus root disease
Phwe = Laminated root rot

Insect Abbreviations

Choc = Western spruce budworm
Debr = Western pine beetle
Depo = Mountain pine beetle
Deps = Douglas-fir beetle
Deru = Spruce beetle
Orps = Douglas-fir tussock moth
Scve = Fir engraver

F6 - Area Identified Infected by Specific Diseases of the National Forests in the Blue Mountains

APPENDIX G

Strategy 1

FOSTER PUBLIC AWARENESS AND PARTICIPATION IN ADDRESSING LONG-TERM FOREST HEALTH ISSUES AS THEY RELATE TO BOTH THE HUMAN AND NATURAL ENVIRONMENTS.

The Forests should involve the public through forums, shared information, use of demonstration areas, and the NEPA process.

Showcase Integrated Pest Management strategies in selected recreation sites and visitor centers with interpretive displays. Foster understanding of forest health and ecosystem interaction among Forest Service managers.

Develop public information and involvement programs that foster public awareness of, and participation in, long-term forest health.

Revitalize the public information program with messages that share the Forest Service vision of the healthy forest, and demonstrate that fire and smoke have intricate and important roles in the function of these forests.

Revise the fire prevention program by stressing that the wise use of fire (planned and unplanned ignitions) can be an effective tool for creating and maintaining healthy forests.

Information is the key to changing the Forest Service's image of "protectionism" to one of "utilization" regarding role of fire in improving the forest. The diverse nature of the visual landscape with patches of early seral vegetation, openings, blackened trees, snags, brushfields and stately older trees needs to be understood as a more natural, healthy landscape than one composed of homogeneous green expanses. Some fire prevention messages/ posters have led the public to believe that green is only color of a healthy forest. The user or traveler through the forest should be provided with information that particulates in the air are as natural to the mountains of Northeast Oregon as the vegetation that cloaks them.

This information effort should involve all levels of the Forest Service, from the Washington Office clear down to individual workers. This revised viewpoint of fire needs to be incorporated (utilizing state-of-the-art methods/techniques) in all forms of media used today for public outreach.

Foster local community (and other) resource management agencies' support for use of fire as a necessary tool to achieve forest health.

A mixture of ownerships with different management practices intermingles with Forest Service lands in the Blue Mountains. The use of fire to promote vegetative diversity and increase forest health entails certain effects which may be feared or not accepted by adjacent landowners. Proactive, coordinated efforts at all levels of Federal, State, and Local governments and publics is essential to fostering the use of prescribed fire as a means to restore and maintain forest health.

Project and Forest planning should foster local public involvement in formulating historic and desired landscape patterns rather than in just commodity versus non-commodity versus non-commodity issues.

We need to convey to the public that we are concerned about managing forest ecosystems that are largely defined within the context of biodiversity. We do not make decisions soley on short-term outputs and services.

Use the Blue Mountains Natural Resources Institute (BMNRI) as a coordinator for public information sharing concerning Forest Health issues.

The BMNRI should facilitate a forum where public views can be expressed, considered, and provided the opportunity to influence decisions. Meetings, presentations, displays, newspaper articles, the Forest Health video, and other public means can be used for information sharing on Forest Health problems and solutions.

Utilize interpretive signs at key points on main roadways to explain pest problems, solutions, and actions being taken.

Clearly state the objectives for both commodity and non-commodity outputs. Give consideration to values, needs, and expectations. Know what is being inventoried and keep a clear idea of the measure used. Think in terms of landscape scale.

Inform publics of the interrelationship between watershed health and forest health.

The BMNRI can take the lead as part of its responsibility for fostering public awareness of natural resource management.

Biodiversity enhancing practices should be demonstrated on selected areas of the Blue Mountains National Forests, and the public should be invited to examine the results.

Forests and the BMNRI should collaborate to conduct public tours, disseminate brochures, and invite the news media to visit these areas.

Strategy 2

REVIEW FOREST PLANS TO INSURE DESIRED FUTURE CONDITIONS ARE APPROPRIATE GIVEN THE PRESENT CONDITION AND TREND OF FOREST HEALTH IN THE BLUE MOUNTAINS.

The three Forests need to define more completely the values, quantities, and expectations for both the commodity and non-commodity resource outputs needed to maintain long-term productivity of their forest ecosystems.

Develop insect and disease management strategies consistent with resource goals contained within the Forest Plans.

Develop a process, consistent with the Forest Plans, which provide for more timely responses to catastrophic events impacting long-term forest health.

It is recommended that Forest Pest Management (R-6) take the lead in identifying forest pest outbreaks and other natural catastrophic events for which a programmatic document would be appropriate.

Require that the effects of genetic, species, and landscape diversity be addressed in project planning activities and Forest Plan updates.

Understanding the relationship between the affects of multiple projects over long periods of time, and across entire landscapes will allow for better estimates of the total ecological effects of management activities.

Integrated pest management and other resource management practices that affect short-term resources, yet best achieve desired future condition and long-term resource goals, should be carefully considered by the Forests.

Where the DFC cannot be achieved within the framework of the plan, amend or modify Forest Plans as needed.

If forests determine that their Desired Future Condition cannot be achieved, the Forest Plans should be appropriately amended. Assurance should be made that current resource Standards and Guidelines will not further detract from the capability to achieve Desired Future Condition if amendment is not readily possible. Forest staff members, including pest specialists, should be assigned to these tasks. Implementing these recommendations would be the responsibility of the Forest Supervisor. Future planning and amendments must ensure consistent management direction across the Blue Mountain Forests.

Where appropriate, implement as soon as practicable selected forest health recommendations to the fullest extent as allowed by the Plan.

Forests should review forest health recommendations **in the context of** Plan direction (Standards and Guidelines).

Ensure that Forest and project level resource planning and management practices will achieve the stated long-term desired future conditions.

Integrated pest management and other resource management practices that impact short-term resources, yet best achieve desired future condition, and long-term resource goals, should be carefully considered by the Forests.

Determine the need to amend and revise policy, direction, and constraints of Standards and Guidelines in allocations managed for timber resources. Ensure that fire salvage activities are allowed where long-term goals and Desired Future Conditions will be achieved.

Where Standards and Guidelines in the Forest Plans refer to conditions, management activities, or objectives that increase biological diversity, but fail to use terminology to indicate so, the Forest Plans should be amended to use diversity terminology (see Wallowa-Whitman Miscellaneous Standards and Guidelines).

Forests and Districts should consider organizational changes to ensure that fire use is assessed and promoted during program and project planning processes, and followed through with implementation.

A Forest Health staff position could be established to guide Districts in their planning and implementation activities. Districts could organize specialty teams to devise landscape mosaics over long-term timeframes and at scales which emphasize biodiversity enhancement. A high level of skilled fire specialists should be maintained to implement these projects.

Develop a multi-year improvement program based on desired future conditions for designated subwatersheds.

Prioritize subwatersheds for treatment based on problem analyses and investments required. Coordinate with other resource areas (i.e. range management) and pursue multiple sources of funding.

Strategy 3

UTILIZE FIRE AND SILVICULTURAL MEANS TO RESTORE AND MAINTAIN FOREST HEALTH IN THE BLUE MOUNTAINS WITHIN THE FRAMEWORK OF THE DESIRED FUTURE CONDITIONS DESCRIBED IN THE FOREST PLANS.

3a-Reintroduce fire as a means to restore and maintain forest health through modifying, diversifying, and rejuvenating forest landscapes.

An analysis of the existing vegetation patterns and specific known fire tolerances of certain plant species indicates that the historic role of fire in the Blue Mountains varied from low intensity surface burns to total stand replacement burns. A similar array of fires is necessary to achieve the vegetational mosaic historically common to the Blue Mountains. However, due to the long period of fire exclusion, a gradual reintroduction of fire to these ecosystems is expected to prevail.

Encourage re-introduction of surface fires back into the ecosystem to protect and maintain stands.

Catastrophic stand replacement fires and catastrophic pest damage can be avoided by converting stands back to seral species on sites that were historically maintained in seral condition by wildfire. This action would enhance wildlife habitat in the short- and long-term.

Develop fire management plans establishing criteria, goals, and objectives for utilizing unplanned and planned ignitions as means to restore and maintain forest health.

In areas where timber and other resource objectives will not be jeopardized unplanned ignitions could be designated as prescribed fires if predetermined criteria outlined in an approved fire management plan were met.

Restore and maintain seral species (as appropriate) on sites that were historically maintained by wildfire.

Initiate a system and process for collecting, storing, and evaluating fire effects data from prescribed fire projects.

A District-level position would facilitate this task, and ensure that information from periodic data and field evaluations is disseminated among the district team.

Provide training for resource specialists that emphasizes the beneficial role of fire in resource management.

Training sessions could be presented by scientists, fire specialists, biologists and ecologists. The thrust of these sessions should address overall forest health in terms of combinations of strategically planned prescribed natural ignitions, underburns, and stand replacement burns.

Consider opportunities to benefit from the use of fire in project-level planning.

Forest, District, and BMPMZ staffs should try to take advantage of these opportunities when available.

Recommend that appropriate jurisdictional agencies or legislative bodies explore effective means of continued fire use while mitigating significant impacts to the air resource.

The 1990 RPA Program recognizes that catastrophic fire "will continue to be a concern until build-up of natural fuel is eliminated or prevented." Land managers also recognize that a major contributor to the existing fuels situation has been fire exclusion. This has resulted both directly, as accumulation of dead and down surface fuels, and indirectly, as insect or pathogen activity increases in late-seral vegetation communities (successional advancement). Achievement of the RPA goal to prevent catastrophic fires in the fire-prone forests of the Blue Mountains will require an increased, on-going use of fire as an effective and practical management tool. Use of state-of-the-art prescribed burning techniques could still result in periodic short-term impacts to air quality. Appropriate agencies and legislative bodies need to be open to on-going evaluation of existing air resource provisions and consider needs for supplemental revisions.

Mimic natural fire regimes with prescribed fire to: 1) Reduce risk of severe fire that could substantially reduce long-term productivity; 2) maintain tree species that occur under the natural disturbance regimes; 3) reduce competition; 4) increase nutrients; 5) prepare sites for seeds or plantings; 6) improve range resources; and 7) create wildlife habitats.

3b-Utilize silvicultural means to restore and maintain forest health through modifying, diversifying and rejuvenating forest landscapes.

Enhance forest health and maintain big game cover through the use of silvicultural systems which create multi-species forest stands with stocking levels low enough to make them less susceptible to pests.

Within land allocations that emphasize timber management, appropriate salvage operations should be conducted as soon after a fire event as possible.

The time lag between tree mortality by fire and retention of sufficient useable wood fiber for a feasible harvesting operation is critical. For some species, this timeframe covers only one year. Once a management decision is made to salvage harvest, processes and procedures should proceed quickly. A review of present methods and the determination of the possible means to 'streamline' NEPA and timber sale planning are necessary to accomplish this recommendation.

Stands with epidemic pests should be given treatment priority based on current losses, potential for future losses, and productivity potential.

Within resource objectives, emphasize the thinning of ponderosa pine stands where high risks of insect- or fire-caused mortality exist.

Stands with epidemic pest infestations should be given treatment priority based on current losses, potential for future losses, and productivity potential.

Treat entire root disease infection centers. Don't use partial treatment to minimize the scale of disturbance, even when infection center size exceeds 40 acres.

Manage roads to assure that they are necessary, and appropriate, and that they address resource concerns, especially potential impacts on elk.

Consider mitigating actions such as more environmentally sensitive logging systems or deferral of green sales in drainages in need of extensive sanitation logging.

Strategy 4

IMPROVE COORDINATION OF FOREST SERVICE LAND MANAGEMENT ACTIVITIES BETWEEN ADJACENT LANDOWNERS AND OTHER GOVERNMENT AGENCIES TO INSURE THAT FOREST HEALTH CONCERNS ARE ADDRESSED.

Conduct studies between the Blue Mountain Forests and their cooperators as part of the Forest Service Economic Diversification Studies Program.

The purpose of these studies is to identify economic opportunities which result from the use of small-diameter wood products on the National Forests of northeastern Oregon.

Develop and promote cooperation among adjacent landowners.

Public and private lands need to be managed in a mutually beneficial manner, especially with regard to Forest Health concerns, which often cross ownership boundaries.

The Blue Mountains Natural Resources Institute, with support from the Forests, should serve as the primary catalyst in building coalitions in which will help to better define long-term productivity, biological diversity, and changing social values.

The applied practices and results of biological diversity enhancement activities should be demonstrated on selected areas within the Blue Mountain National Forests.

The Forests and the BMNRI should collaborate to conduct public tours, disseminate brochures, and invite the news media to visit these areas.

Foster awareness among jurisdictional agencies (i.e. Oregon Department of Environmental Quality) and legislative bodies regarding the beneficial role fire could play in restoring and maintaining forest health.

Promote increased use of workshops, presentations, and training by Forest pest specialists.

Among our managers, there is a lack of understanding of how Forest Health on ecosystems interact. The BMPMZ should work with District and Forest staffs on alleviating this situation.

Improve coordination between Regional resource staffs in order to establish guidelines for mitigating conflicts between implementation of Forest Health strategies and maximizing resource goals.

Forest Pest Management (FPM) and other resource staffs should investigate ways to share information and reduce conflicts between pest management strategies and resource goals.

Study the feasibility of encouraging companies (or retool existing companies) that can harvest and process dead lodgepole, dead ponderosa pine, and small-diameter trees and wood products of sub-sawlog size.

Regional strategy (lottery) monies could be used, and perhaps the technology transfer agreements could be developed to encourage establishment of such companies.

Promote the awareness and knowledge of pests, pest damage, and effective control options.

There may be an opportunity to improve participation in suppression efforts by landowners that have aversions to "spraying" and other, more long-term techniques.

Expand monitoring of pest populations on all forest ownerships.

The BMNRI would provide the focus and coordination for this monitoring.

Continue close coordination with state pest specialists.

Cooperation with State Forestry departments in Forest Health assessments on state and private lands is encouraged. The BMNRI could facilitate cooperation.

Meet and discuss Forest Health concerns on municipal watersheds with appropriate local officials.

Forest insect and disease epidemics and large wildfires threaten the quality and productivity of watersheds. Forests should discuss the potential for such occurrences to create problems in municipal watersheds.

The effects of implementing the Tri-Regional Anadromous Fish Policy on diversity, long-term productivity, and desired future condition should be addressed at all levels of planning and implementation.

Anadromous fisheries are an important feature of forest diversity. Restoration and maintenance of these fisheries is a desirable activity. Live, healthy trees maintained over time are essential for the soil integrity and shade required for adequate fish habitat.

Strategy 5

PROMOTE INTEGRATED RESOURCE ANALYSIS TO INSURE ADEQUATE CONSIDERATION OF FOREST HEALTH NEEDS IN TERMS OF BIOLOGICAL DIVERSITY, LONG-TERM PRODUCTIVITY, WATERSHED VALUES, INSECT AND DISEASE MANAGEMENT, AND CUMULATIVE EFFECTS ON A LANDSCAPE SCALE.

Direct Districts of the Blue Mountains National Forests to develop individual Forest Health Implementation Plans.

The Pine Ranger District (WAW) accomplished this is in 1990. Such plans identify District-level goals and objectives and appropriate tasks for improving ecosystem health and achieve Desired

Future Conditions. The development of these plans should be done by Districts with assistance from the BMPNZ.

Provide for the long-term maintenance of "old-growth" forest allocations and recognize the role such allocations and their dependent species play in maintaining forest health.

Within each designated planning area, set aside "old-growth" core, transition, and corridor habitats.

Develop operational criteria for achieving biological diversity and healthy forests.

Identify which elements of the ecosystem are being considered in any given project. Specify measurements or characteristics that evaluate or distinguish these elements. Describe how the differences between elements are meaningful for management decisions.

Arrange stand size and successional stages to provide forage, cover, edge habitat, and other special needs within each plant community in order to meet biological diversity and forest health objectives over time.

Emphasize the growth and supply of merchantable trees in the sizes, age-classes, quality, quantity and species mixes that most clearly address market demands within the framework of forest health goals.

Project planning should address the question of appropriate levels of retention and recruitment of snags and down woody material.

Restoration and maintenance of forest health must be addressed within the context of the Tri-Regional Anadromous Fish Policy.

Promote the concept of subwatershed planning.

Project activity should be concentrated in space and time over those areas having the highest needs for treatment. It should be realized that Standards and Guidelines may be exceeded in the short-term in order to meet long-term goals and Desired Future Conditions. Access management should be used to minimize watershed disturbance following project completion.

Recommend that WO agency and Department staffs work with Congress to develop a means of providing funds for rehabilitating stands and doing other resource management work when a situation arises that would not result in collection of adequate K-V funds.

Provide restoration of Forest health in portions of management areas, while providing cover for the short-term in adjacent stands.

While carefully considering scale, treatments can be accomplished over time that maintain acceptable cover in management areas.

Further promote the concept of access management.

Access management and restricted hunting could be used to minimize disturbances of big game animals where cover has been reduced for the purpose of enhancing long term forest health.

Promote enhancement of riparian areas through stand conversion. Species composition, stand density, and vigor should all be taken into account, and seral species should be favored where possible.

Such management direction would be far more effective than is the present policy of protecting already extant compositions which are often destroyed by a host of insects and diseases.

Promote the use of stocking level control in old growth allocations.

Where scheduled harvest activity will meet wildlife objectives, stocking level control should be used to maintain vigor and minimize episodes of bark beetle depredation.

Implement stand treatment prescriptions to increase stand vigor and convert stands back to less pest-susceptible seral species. Use group selection systems where needed to achieve unevenaged management goals.

Stands that have been converted to shade-tolerant, pest-susceptible true firs and Douglas-fir because of fire exclusion and partial cutting (individual tree selection) often need to be treated in order to achieve Desired Future Condition.

Implement a strategy whereby benefiting resources fund rehabilitation work.

Timber values, which have traditionally been used to generate these funds, should not automatically be used to fund this work, especially when no timber-related value is derived from a project.

Determine what combination of pesticides and non-chemical treatments will best provide short- and long-term Forest Health in the Blue Mountains.

This will require an analysis using expertise from Research (FPM R-6), TM (R-6), and the Forests.

Direct silviculturists and pest specialists to work together to identify opportunities to improve diversity within the framework of Forest Health.

This should be a task for silviculturists, wildlife biologists, ecologists, and pest specialists with the BMPMZ.

Stand situations that are diverse, yet are especially susceptible to pests, should be avoided when they threaten long-term goals and Desired Future Condition.

An example is the structural diversity achieved by classic unevenaged management (through individual tree selection) in mixed conifer stands which favors high stocking of shade-tolerant, pest-susceptible trees.

Keep trees growing vigorously so they are less vulnerable to insect- and disease-caused damage. Encourage growth, healthy crowns, and mixed-species stands where appropriate to planned objectives.

In mixed-conifer stands, strive to keep less than 30 percent of stands in spruce budworm host species (spruce, Douglas-fir, true firs). Mixed stands are considered (to be) less susceptible to defoliators then pure stands.

Establish a mosaic of age classes across watersheds, districts, and forests.

Consider resource objectives that will allow longer rotation lengths, and cultural practices that emphasize value production over volume production. This will generally mean larger tree size, cleaner boles, smaller knot size, more ponderosa pine, and wider spacings of the trees. Within managed stands, the ages might range from about 80-250 years, depending on the site, species, and objectives. Rely on natural regeneration whenever possible. Use shelterwood, group cuttings, and selection harvest systems, rather than clearcutting, where conditions permit.

Use fire as a primary tool in achieving vegetation management objectives. Increased use of fire should be used to reduce competition, increase available nutrients, manipulate species composition, prepare sites for natural or artificial regeneration, develop special habitats, and reduce wildfire hazards.

Use of ground based yarding equipment should be restricted to specified locations and seasons of operation in order to reduce their negative effects on the soil resource. Explore ways to encourage light cable systems.

Emphasize retention of organic matter in management activities. All sizes of material should be retained, and if the given prescription allows, the target amount should be 30 tons per acre.

Assign measurable range management outputs to: range vegetation, riparian vegetation, grazing management, and noxious weeds as part of the allotment management plan process. Include wild horses and big game, if applicable.

Do not expose forest streams to solar radiation above the objective level. Leave streamside vegetation to maintain shading and water temperature standards. In general, water yield increases as the degree of cutting increases, although the amount of increased yield variation occurs by watershed. Model quality, quantity and timing of stream flow before project activities in order to estimate the effects of planned activities.

Evaluate the effectiveness of harvest and cultural methods in meeting visual objectives. Aesthetic qualities need to be raised to a higher level than has been the case in the past.

Protecting habitat for insect predators should play an important role in the suppression of pests. Important habitats for birds and ants such as snags, ant mounds, and woody debris should be protected and managed.

All possible effort should be expended to keep snag levels that will support *highly viable* populations of primary excavators, as such attempts will aid greatly in maintaining long-term productivity for multiple resource values. Review Forest Plan Standards and Guidelines regarding snag retention in light of recent unpublished research findings by Evelyn Bull of the PNW Research Station.

There is strong direction to protect and manage for old growth values; also recognize the need to link old growth habitats through a system of corridors.

Follow these operational criteria for achieving biological diversity:

- Identify which elements of the community are being considered, e.g. tree species, bird species, forest types, stand conditions, age class, and junctions with other communities.

- **Focus research on the following:**
  - **long-term forest productivity;**
  - **priority forest pests, resource interactions, and management needs;**
  - **biological diversity;**
  - **social and economic values; and**
  - **anadromous fish habitat.**

Define and develop the standards, criteria, procedures, and tools for monitoring forest health.

Forest Pest Management (WO, R-6) and Forest Health RD&A should place high priority on developing these aids, and improving appropriate technology transfer tools.

Initiate research that will more clearly define the acceptable range of cumulative effects of equipment-caused soil disturbance on costs, benefits, growth, yield and long-term productivity.

Since soil organic matter levels and compaction appear to be the main variables linking management activities to long-term site productivity, it is essential that the soil and all its properties be protected (for helpful guidelines given by interdisciplinary determinations of desired residues, see R-6 fuel management notes, 1979).

Through the BMNRI, conduct problem analyses of forest health issues.

Additional pest suppression research should be pursued and present technology (e.g., species manipulation) be demonstrated.

Encourage research and demonstration of stand management techniques and nutrient management on deficient sites as practical means of highlighting both prevention and management of pests through improving tree vigor.

Refine recommendations for Black stain root disease in small sawlog-size ponderosa pine.

This request for forest disease research should be made through the BMNRI.

Refine the need to treat subalpine fir stumps to protect stands from annosus root disease.

This request for forest disease research should be made through the BMNRI.

Increase the effectiveness of biological controls.

Continue analysis of formulations, application rates, timing, etc., to maximize effectiveness and efficiency of these controls, thus making their use more attractive.

Research efforts should assist in maintaining the genetic diversity in forest trees. Isozyme analysis should be used for assessing the affects of various management activities on genetic diversity.

The recommended steps to reduce or eliminate factors which adversely influence genetic diversity are: Collect seed from a broad base of trees and stands of local origin; use nursery and reforestation practices that minimize seed and seedling losses; and take advantage of natural regeneration where appropriate.

Blue Mountains Natural Resources Institute should assist in the research and promotion of a better understanding of the role of fire in Blue Mountains.

Emphasis should be placed on understanding the effects of fire on plant and animal species and their habitats; the improvement of burning practices under varying climatic and vegetation conditions; and analytical designs for fire monitoring data.

Initiate and/or continue to conduct fire-effects study on 1986, 1987, 1988, 1989, and 1990 fires on the three National Forests.

Post-fire vegetational monitoring plots (transects and photo points) were established on certain sites of the 1986 wildfires. Several of these post-burn plots existed prior to the fires, and were used to provide data for the *Plant Associations of the Wallowa-Snake Province*. In addition, several of these classification study plots exist on areas that were burned more recently (1989, 1990). Establishment of post-burn plots in areas where none yet exist would be beneficial to this monitoring process. On-going data collection and annual evaluations could suggest positive changes in management practices within the next decade. Cyclic monitoring of some of the established plots is already planned for the future.

The Blue Mountains Natural Resources Institute should initiate research that verifies that smoke from forest fuels may have beneficial effects with regard to suppressing some forest insects and pathogens.

The generation of smoke from forest fuels is a common occurrence in many coniferous forest communities. The specific relationships by which smoke may serve as a suppressing agent are not clearly understood, but data and observations from a few studies indicate that smoke has an inhibiting effect on germination of mistletoe seed, the spores of some root disease pathogens, and mycelial growth of some other forest tree fungi.

Initiate research on stressed sites.

Efforts should include investigation of more efficient monitoring, techniques assessments of the success of various mechanical rehabilitation measures, and a general assessment of the extent of management-imposed site stress.

Management induced stress may be an important factor in increasing the vulnerability of managed stands to insect and disease attack. Although such effects are thought to exist, their magnitude has not been quantified in the Blue Mountains, so they should be monitored carefully. Information generated from such monitoring efforts will be useful in refining management prescriptions and meeting long-term forest health objectives.

Initiate research to investigate and quantify the affects of various management practices on plant growth and vigor.

Although it is recognized that certain activities have adverse impacts on plants, its difficult to quantify these effects. Increased capability for measuring long-term affects will allow for better trade-off analyses in the decision making process.

Strategy 7

DEVELOP TECHNOLOGY AND INFORMATION RESOURCES IN CONJUNCTION WITH INTEGRATED RESOURCE MANAGEMENT IN ORDER TO BETTER ADDRESS LONG-TERM RESTORATION AND MAINTENANCE OF FOREST HEALTH.

- Develop models for the following:

- **-- mountain pine beetle impact on ponderosa pine;**
- **-- Douglas-fir beetle-caused losses and population trends;**
- **-- true fir losses from stem decays;**
- **-- fir engraver-caused losses;**
- **-- spruce beetle-caused losses; and**
- **-- cumulative effects across forest landscapes.**

These models would support integrated resource management.

Promote methods for adding Integrated Pest Management input to resource management prescriptions.

Pest specialists should be consulted during the environmental analysis process, or be members of ID teams on projects where pest concerns and issues are considered important.

Provide training to District level personnel in biological diversity principles, philosophy, and adaptive management activities as they relate to healthy forests.

Workshops similar to the Regional Biodiversity Workshop recently held at Spokane should be available to Ranger Districts. Zone Ecologists, and zones Forest Pest Managers would be responsible for conducting the workshops.

Support forest health objectives and economic diversity consistent with the Pacific Northwest Strategy by providing greater opportunities to remove wood fiber which is excess of the amount required to supply noncommodity resources. Techniques and sound economic methods should be developed that encourage such removal. Examples are chipping in the woods, small diameter thinnings, cull removal, light cable systems, etc.

Establish a demonstration area in the Blue Mountains that studies and applies new technologies to enhancing our knowledge of forest health.

Implement full use of available pest simulation models and pest specialist expertise for the next update of Forest Plans.

Recent revisions of FSM 1922.04b and 1922.155, require: (1) Resource protection technology must be integrated into the planning process; (2) addition of direction to ensure that management prescriptions provide for prevention of pest outbreaks; and (3) addition of direction to plan for pest prevention.

Review stand examination and Forest Inventory designs for their completeness in collecting data needed for pest models.

Forest Pest Management (FPM R-6) and Timber Management (TM R-6) should be responsible for the revisions needed in data collection programs, and should provide documentation for Forest use.

Review and monitor training of stand examiners, both contract and FS, to ensure that the data required to run pest simulation models is being accurately collected.

Timber Management, Forest Pest Management (R-6), and BMPMZ should determine if training standards are adequate, and if not, make necessary adjustments.

Use INFORMS technology wherever possible in project analysis.

Technology which is presently being refined for the Five Points EIS on the La Grande RD by FPM (WO) and the District will be the state-of-the-art; such multi-pest simulation and multi-resource decision-making models will be more widely available, and should be used to assist in future environmental analysis.

Increase the use (by Forest and District personnel) of currently available pest simulation models. Increased training in available and newly-released models is recommended.

Zone pest specialists would be responsible for assuring that resource staffs are familiar with the use of these tools.

Give priority status for completion of GIS products that will assist in resource management.

BMPMZ and FPM (R-6) staffs have identified products that will monitor, hazard rate, and track distribution of key pests. These tools will be critical for effective resource management. Priority development of these products should be a responsibility of the Regional GIS Coordinator.

Increase the resources available to implement recommendations directed at improving and maintaining Forest Health.

The BMPMZ and other forest units will require additional staffing to handle the increase in workload for Project implementation.

Identify potential pest losses and outbreaks through risk-rating and monitoring, and use that data when scheduling management activities.

Apply systems to risk-rate stands, analysis areas, timber types, and plant communities for susceptibility to pests. In conjunction with this, establish demonstration areas which will be carefully monitored. The combination of these two tools should go a long way in helping to estimate potential resource losses and setting management priorities.

Encourage use of non-traditional forest product sales to help accomplish IPM.

Use regional strategy (lottery) monies to encourage development of industries using under-utilized forest products (fuelwood, post, poles, etc.). The BMNRI can help in coordinating this effort.

Zone pest management specialists are responsible for supporting and providing assistance for many of the tasks that will eventually restore and maintain Forest Health. Regional pest management (FPM) should improve its support for Forest zone pest specialists.

The need for dwarf mistletoe suppression funds is diminishing, but the funds should remain available.

Most control work can be accomplished within the scope of vegetative management projects. However, there will continue to be cases where funds will be needed to accomplish suppression work.

Develop better ways to economically evaluate benefits and costs of treatment in suppression projects.

If areas are to be treated to protect resource values other than timber production, better ways may need to be developed to economically evaluate the treatment used to protect these resources; especially when such areas compete for suppression funding with timber production areas.

Provide for rapid access to people qualified in pest suppression technology.

Integrate GIS technology in pest suppression planning.

Develop boilerplate language or position papers which will simplify development of site-specific NEPA documents.

It is recommended that Forest Pest Management (FPM R-6) and Environmental Affairs (R-6) identify these needs and work with Forest staffs to develop appropriate documents.

Develop programmatic Environmental Impact Statements to address specific recurring catastrophic events.

It is recommended that Forest Pest Management (R-6) take the lead in identifying forest pest situations and other natural catastrophic events for which programmatic documents would be appropriate, and develop these documents.

Establish a Region-wide list of personnel experienced in NEPA projects.

There is the need to identify available personnel to serve on "SWAT" teams that can respond quickly to catastrophic events.

Encourage responsible officials to quickly determine the levels of NEPA analysis required for responding to various catastrophic events.

Use of borax to control the colonization of freshly-cut stumps by *Heterobasidion annosum* by specifying C-Provision C6.412 should be required in applicable circumstances.

Stump treatment should be required in stands where true fir will be managed in the future; in marginal ponderosa pine stands; on certain evaluation plantation sites; and all recreation sites.

Fully develop (and operationally test) new methods of manipulating insect populations in the Blue Mountains.

Example: Bait and cut strategies, successfully accomplished in other areas, have not been used in the Blue Mountains. This should be done by the BMPMZ in cooperation with FPM (R-6).

Develop new (and improve the old) information on effectiveness of available control technology for Forest diseases and insects.

Example: Determine the effectiveness of borax stump treatment for annosus root diseases. Research needs that are important for land management decisions must be priority work items for Forest Disease Research. The BMNRI should coordinate with research groups, pest specialists, and land managers to address research needs.

Increase the levels of pest monitoring in order to determine the effectiveness of the technology now in use.

Example: Most budworm suppression results have not been followed beyond the year of treatment.

Direct the Region to develop guidelines for use of the behavior-modifying chemicals that are available for monitoring and managing forest insects. Provide training for Zone pest specialists in the use of these semiochemicals.

Pest specialists need guidelines and training on when, where, and how to use existing and new technology.

Place more emphasis on detecting conditions that make stands susceptible to pest-caused damage.

Hazard rating tools, INFORMS products, GIS products, etc., can allow for more efficient monitoring and evaluation of forest pests. Increased use of existing (and development of new) technology is recommended.

Increase the organizational resources for monitoring.

In order to perform effective Forest Health Monitoring in the Blue Mountains, it is recommended that there be an addition of personnel to the BMPMZ, or establishment of a Forest Health Unit or adaptive management position under the auspices of the BMNRI.

Short-term solutions to pest problems should explore the full range of IPM strategies (FSH 3409.11). Long-term solutions must help in reducing the need for pesticides so that they are *rarely* used in the future.

Establish a demonstration area in the Blue Mountains for the purpose of conducting intensive monitoring, evaluating post burn effects, and testing application of fire.

The approach towards managing ecosystems involves many unknowns, some of which will only become apparent long after the practitioner has left the scene. A structured monitoring process and ongoing evaluation of all effects of fire will be crucial to the ability to plan and implement those activities that achieve desired biodiversity. BMNRI should take the lead in this effort.

Develop more accurate and user friendly watershed models for Forest and project planning use.

The controversiality of management activities in drainages that support anadromous fisheries requires that we accurately predict impacts well into the future. Good watershed models will assist in better predictions, more detailed monitoring and evaluations, and more precise record keeping.

Refine pesticide monitoring techniques so that they provide land managers, cooperators, and the public with timely and accurate information regarding effects of pesticide applications on water quality objectives.

If prescribed pesticide applications are not effective in meeting water quality standards or objectives, they must be modified immediately or halted completely. Land managers require timely and accurate information upon which to base such decisions and evaluate tradeoffs.

The three Forests should assess the need for reestablishing USGS gauging stations on or near the National Forests.

These stations could provide valuable information about down stream affects of Forest Service activities. Non FS activities could also be monitored to help prepare cumulative effects analysis.

Increase monitoring (and refine the process) of the effects of management activities on soil and water.

Management activities that occur in areas with sensitive soil and water resources, or are of a size or intensity that could adversely affect soil or water conditions, would require a monitoring plan to assure that impacts remain within desired thresholds. Mitigation measures need to be monitored for effectiveness.

As modifications of forest landscapes occur, involve the BMNRI in studies which interpret results of Forest monitoring data regarding richness and evenness of plant and wildlife species.

APPENDIX H

A BRIEF PERSPECTIVE ON FOREST PESTS

IN DEVELOPED RECREATION SITES

Robert D. Harvey, Jr. FPM, Pacific Northwest Region

Developed recreation site managers are directed by FSM 2332 to perform a comprehensive inspection of each site, annually, prior to operation. Part of the reason for this examination is to identify trees that pose an unacceptable hazard to people or their property, and pests that are negatively impacting the site, then expedite treatments appropriate to minimize the hazard or impact. Following are major pest categories and impacts by agents therein, on developed recreation sites:

Root Diseases

Root diseases of particular concern are laminated root rot caused by *Phellinus weirii*, Armillaria root disease caused by *Armillaria ostoyae*, and Annosus root disease caused by *Heterobasidion annosum*. Each of these fungi must be identified, as treatments differ and impacts can vary significantly. In general, root diseases cause mortality and predispose trees to windthrow, breakage, and/or attack by bark beetles. In established sites, impacts from root diseases are generally detrimental and treatments are often highly disruptive to the site. However, in proposed sites where spread can be arrested, openings and snags caused by root diseases could be seen as valuable and impacts viewed as beneficial.

Butt and Stem Decays

Butt and stem decays of major concern are Schweinitzii butt rot caused by *Phaeolus schweinitzii*, rust red stringy rot caused by *Echinodontium tinctorium*, and red ring rot caused by *Phellinus pini*. Butt and stem decays predispose trees to breakage. Signs of internal decay are sometimes difficult to detect or absent. Treatment usually involves tree removal or topping, or target removal. Impacts can range from quite severe, if most old-growth trees are unacceptably hazardous, to potentially beneficial, if only a few scattered trees are affected and treatments can minimize hazard while improving wildlife habitat.

Dwarf Mistletoes

Dwarf mistletoe-caused hazards are generally associated with limbs, but occasionally with main stems. Hazardous trees are characterized by having large witches brooms and/or dead tops. Even where major brooming or dead tops are absent, infection reduces tree vigor so that secondary attack by bark beetles or colonization by root disease causing fungi has a higher probability of occurrence. Direct impacts to the site range from slightly detrimental, requiring only branch or top pruning, to beneficial in providing wildlife cover and nesting sites. Indirect detrimental impacts resulting from predisposition to attack by other agents can, however, be major, depending on the magnitude of the epiphytotic.

Foliage Diseases

The major foliage disease of concern is Elytroderma needle blight caused by *Elytroderma deformans*, however, any of the minor needle cast diseases can cause problems if they occur with enough frequency to significantly reduce the vigor of host trees. While visual quality can be significantly reduced in areas where Elytroderma needle blight is severe or during years when needle cast diseases are severe, the most damaging impact on sites is secondary by predisposition of the hosts to damage by other agents such as root diseases and bark beetles.

Defoliators

Any of the defoliators can cause detrimental impacts ranging from minor to quite significant depending on the insect, host, and magnitude and duration of infestation. With minor defoliation, visual quality can be impaired. Severe defoliation, however, can cause top-kill, direct mortality, or predisposition of affected trees to attack by other damaging agents.

Bark Beetles

Bark beetles are frequently secondary agents attracted to trees of reduced vigor. As populations build, the sheer numbers of insects can overwhelm vigorous green trees and cause mortality over widespread areas. In these cases the impacts on developed recreation sites can be devastating. If bark beetles kill only a few selected individuals over a large area, however, impacts can be beneficial by providing wildlife habitat. Treatments are available that can reduce the probability of major infestation by bark beetles.

The magnitude of negative impacts caused by pests can be significantly reduced if a quality vegetation management plan is developed and used for management of each site. As the plan is developed and problems discovered, treatments can be implemented. Thereafter, by following the plan, impacts on vegetation that can lead to insect or disease damage can be minimized.

GLOSSARY

GLOSSARY

ACTIVITY AREA

The total area of ground affected by an activity that remains a feasible unit for sampling and evaluation.

ADULT

Fully grown, sexually mature stage of an insect.

ALL-AGED

A forest stand that contains trees of all or almost all age classes, including those of exploitable (useable) age.

ALLOWABLE SALE QUANTITY (ASQ)

The quantity of timber that may be sold from the 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."

ALLUVIAL

The term which refers to recently transported and deposited materials. Alluvium generally refers to sand, mud, and other sediments deposited by streams.

ANADROMOUS FISH

Those species of fish that mature in the sea and migrate into fresh water streams to spawn. Salmon and steelhead are examples.

ARTIFICIAL REGENERATION

Renewal of a tree crop by direct seeding or planting.

ASQ (see ALLOWABLE SALE QUANTITY)

BARK BEETLES

Common name applied to the insect family Scolytidae, a group of beetles whose adults bore through the bark of host trees to lay their eggs, and whose larvae tunnel and feed under the bark.

BASAL AREA

The area of the cross section of a tree inclusive of bark, at breast height (4.5 ft, 1.37 m).

BIODIVERSITY

The variety, distribution and structure of plant and animal communities, including all vegetative stages, arranged in space over time, that support self-sustaining populations of all natural and desirable naturalized plants and animals.

BIOMASS

Total mass at a given time of living organisms of one or more species or tissue per unit area, or all species in a community.

BLOWDOWN

Trees uprooted by wind.

BOARD FOOT

Unit of measurement represented by a board 1 ft long, 1 ft wide, and 1 in thick.

BOLE

The trunk or stem of a tree.

BROADCAST BURNING

Allowing a controlled fire to burn over a designated area. It is used for the purpose of reducing fuel hazard, as a silvicultural treatment, or both.

BUDBURST

The opening or flushing of vegetative buds; it represents beginning of shoot and foliage growth.

BUTTROT

Decay, often in the root system, but sometimes extending up to 12 feet into the main bole.

CANOPY

The more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody growth.

CANOPY CLOSURE

In a stand, the progressive reduction of space between crowns as they spread laterally, increasing the canopy density.

CATASTROPHIC PEST-CAUSED DAMAGE (LOSSES)

A level of insect- or disease-caused tree mortality and/or damage, such that resource management goals and objectives are significantly hindered, and Desired Future Condition described in Forest Plans cannot be achieved in either the short-term or the long-term.

CCF

(see CROWN COMPETITION FACTOR)

CLEARCUTTING

Removal of virtually all trees in a timber stand in one cutting operation. Leads to the establishment of an even-aged stand.

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.

CLIMAX SPECIES

Those species that dominate a forest stand in either numbers per unit area or biomass at climax.

CODOMINANT

Trees with crowns at or near the top of the canopy. In silviculture, it is one of the four main crown classes, and is recognized on a basis of relative status and condition in the stand.

COCOON

A covering composed partly or wholly of silk spun by an insect larva as a protective shelter for the pupa.

COMMERCIAL THINNING

Any type of thinning of trees which produces merchantable material at least equal to the value of the direct costs of timber harvesting.

COMMODITY

A transportable resource product with commercial value--all resource products which are articles of commerce.

COMMUNITY

An assemblage of populations of plants and animals.

COMPACTION

The packing together of soil particles by forces exerted at the soil surface.

COMPOSITION

The amount of representation of tree various species in a forest stand, usually expressed as percent by volume or basal area of each species, or, at the seedling stage, as percent by numbers of individuals.

CONK

Representation of tree species in a forest stand, usually expressed as percent by volume or basal area of each species, or as percent by number at the seedling stage.

CONK

Visible fruiting body of a tree fungus.

CONFLAGRATION

A large destructive fire (see WILDFIRE).

COVER

Vegetation used by wildlife for protection from predators, to ameliorate conditions of weather, or in which to reproduce (see also HIDING COVER; THERMAL COVER).

COVER TYPE, FOREST

The forest vegetation type which occupies a given site, the term conveys no implication as to whether the vegetation is temporary or permanent.

CROWN COMPETITION FACTOR

A measure of stand density as a proportion of that achieved by a stand of free-to-grow, open-grown trees.

CROWN FIRE

A fire that is sustained by, and spreads through, tree crowns.

CROWN KILL

Portion of crown with foliage killed by defoliation or secondary causes (e.g., by bark beetles).

CULL

Logs with defects, caused primarily by rot, that do not meet minimum standards for net merchantable volume.

DAMAGE

Any effect of insect feeding or disease infection deemed deleterious to some management objective or objectives.

DBH

(see DIAMETER AT BREAST HEIGHT)

DECAY

Deterioration of woody tissue that results in defect which may or may not predispose trees to failure.

DECLINE PHASE (III)

Usually the third year of a tussock moth outbreak, the year in which the density of insects declines sharply.

DEFECT

Damage caused to trees by biotic or abiotic agents that result in loss of merchantable volume or value in terms of the timber resource commodity.

DEFOLIATION

A process in which some or all leaves are removed from a tree by insects, fungal attack, and/or other agents; it is not to be confused with natural leaf fall.

DEGREE-DAY

A measure that accounts for both time and temperature during a given period; 24 hours at a temperature that is 1° above a specified threshold temperature equals one degree-day (°D).

DESIRED FUTURE CONDITION

A term used to reflect the hoped-for results to be achieved through implementation of the Forest Plans in both the short- and long-term.

DETECTION, DETECTION SURVEY

Pest management activity conducted for the purpose of effecting early discovery of insect outbreaks or incipient pest problems.

DIAMETER AT BREAST HEIGHT (DBH)

The diameter of a tree 4.5 feet above average ground level, except that in National Forest practice it is measured from the highest ground level at the base of the tree; it is abbreviated to dbh.

DIAPAUSE

Condition of suspended animation or arrested development during the life cycle of an organism. For example, overwintering budworm larvae undergo diapause.

DIRECT CONTROL, DIRECT SUPPRESSION

Any method or measure undertaken as a direct or remedial action to curb outbreaks in progress by killing insects or protecting foliage (e.g., felling and burning infested trees, or applying an insecticide treatment).

DISEASE

Biotic or abiotic disturbance to plant structure or tissues resulting in damage.

DISPERSAL

The act or result of dispersing or scattering; it usually refers to the distribution of adult insects or to the redistribution of larvae after eggs have hatched.

DIVERSITY

The distribution and abundance of different plant and animal communities and species.

DOMINANT

(1) A plant species within a community (or more narrowly defined assemblage of components) that exerts the greatest influence because of its abundance or activity; (2) a tree or group of trees, that are largely free growing, which occupies the uppermost layers of the forest canopy.

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.

EARLY LARVAE

Larvae that have recently issued from eggs, the term usually signifies the first and second instars.

ECLOSION

Issuing of a larva from an egg.

ECOLOGICAL PROCESSES

The interaction of environmental systems in promoting change in the environment.

ECOLOGY

The study of plants and animals in relation to their environment.

ECOSYSTEM

An interacting system of organisms considered together with their environment; e.g., marshes, watersheds, and lakes are ecosystems.

EFFICACY

Effectiveness. In terms of an insecticide, it means the ability of a product to control a specified target pest or to produce a specified action.

EGG MASS

Eggs deposited in a group by a single female.

ENDEMIC

Restricted to, and constantly present in, a particular locality.

ENTOMOPATHOGENIC

Refers to microorganisms and viruses capable of causing disease in insect hosts.

ENVIRONMENT

The aggregate of physical, biological, economic, and social factors affecting all organisms in an area.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

The Federal Agency with primary responsibility for enforcement of environmental regulations.

EPA

(see ENVIRONMENTAL PROTECTION AGENCY).

EPIDEMIC

Prevalent and spreading rapidly; widespread. Often used in reference to a rapidly increasing and spreading population of insects.

EPIZOOTIC

An outbreak of disease in which many cases occur; a disease or phase of a disease of high morbidity and one that is only irregularly present in recognizable form.

ESTABLISHMENT

Growing trees until they can be considered established; that is, the stage where trees are safe from normal adverse influences such as frost, drought, weeds or browsing, and no longer need special protection.

EVALUATION SURVEY

A systematic survey in which the current and potential significance of an insect or disease outbreak is appraised.

EVEN-AGED

The condition of a forest or stand composed of trees having no (or relatively small) differences in age.

EVENAGED MANAGEMENT

The application of a combination of actions that results in the creation of stands in which trees of essentially the same age grow together. Managed even aged forests are characterized by a distribution of stands of varying ages (and therefore tree sizes) throughout the forest area. The difference in age between trees forming the main canopy level of the stand usually is within 20 percent of the average age of the stand at harvest rotation age. Regeneration in a particular stand is obtained during a short period at or near the time the stand has reached the desired age or size. Clearcut, shelterwood, and seed tree cutting methods produce even aged stands.

EVAPOTRANSPIRATION

Water loss to the atmosphere by evaporation from soil surfaces, lakes, streams, and by transpiration from plants.

FIELD CAPACITY

The amount of water held in the soil against the force of gravity.

FIELD EXPERIMENT

A test conducted in the field to evaluate a pesticide that shows promise in laboratory tests.

FLUSH

A fresh growth of foliage.

FOCI

Groups of diseased trees, or those sites with infected material (inoculum) in the soil that can result in disease.

FORAGE

Food for animals.

FORB

A broadleafed herb; an herb other than grass.

FOREST CANOPY

The crown cover or upper foliage of forest trees.

FOREST HEALTH

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

FOREST LAND

Land which is at least 10 percent occupied by forest trees of any size (or formerly having had such tree cover) and not currently developed for nonforest use.

FORMULATION

A packaged active ingredient plus various inert materials that a commercial manufacturer of pesticides supplies to users.

FRASS

Solid larval insect excrement.

FUEL

Living or dead plant material that will carry and sustain a forest fire.

FUEL LOADING

The amount of fuel present, expressed quantitatively as weight of fuel per unit area (usually, tons per acre).

FUELS

Any material that will carry and sustain a forest fire, primarily natural materials, both live and dead.

FUNGUS

Plants without differentiation in stems, roots, or leaves (thallophytes) that have no chlorophyll and reproduce by spores.

GAME

Wildlife that are hunted for sport and regulated by State game agencies.

GROUP SELECTION

A modification of the selection system in which trees are removed in small groups.

GUIDELINE

An indication or outline of policy or conduct.

HABITAT

The place where a plant or animal naturally (normally) lives and grows.

HABITAT TYPE

The area capable of supporting one plant association.

HAPHAZARD BURN PATTERN

The resulting burn pattern from a fire burning under its own terms within the surrounding environment and existing climate/weather, not being influenced by humans, except when it's the resulting burn pattern when prescribed fire is implemented by an ecologist with a drip torch.

HAZARD

Probability of tree mortality or damage by an insect or disease.

HAZARD-RATING

Any procedure that produces an index of the relative likelihood of a tree experiencing mortality or damage by a pest.

HERBACEOUS VEGETATION

Seed-producing plants that do not develop persistent woody tissue above ground, includes forbs and grasses.

HIBERNACULUM (plural, HIBERNACULA)

Silken shelter spun by a budworm larva in which it overwinters.

HIDING COVER

Vegetation that provides a screening for wildlife from predators. Usually used in conjunction with big-game habitat requirements.

HIGH-GRADE LOGGING

Removing only the most profitable trees from a stand.

HIGH-RISK

Conditions resulting in a high probability or likelihood of occurrence, especially in connection with tree susceptibility to insect attack.

HOST

Any organism on or within which another organism lives.

HOST-TYPE

Forest composed primarily of tree species that are hosts for a specific insect species.

IMPLANT (technique)

Method used to introduce chemicals into tree tissues by drilling a hole into the woody tissue and implanting the chemical in a solid form. The chemical is slowly absorbed and translocated by the tree.

INFESTATION

Presence of insects in sufficient numbers to produce visible defoliation, topkill, tree mortality, or other abnormalities which can be seen from the air.

INFILTRATION RATE

The rate, usually expressed in inches per hour, at which rain or irrigation water enters the soil.

INOCULUM

Any part of a pathogen capable of growing and causing infection.

INSOLATION

Solar radiation as received by the earth. May cause damage to trees and other plant growth under certain conditions (e.g., sunscald). Also termed solarization.

INTOLERANT SPECIES

A kind of plant that grows poorly or dies in competition with other plants.

INSECTIVOROUS

Feeding chiefly on insects.

INSTAR

The term for an insect before each of the molts (shedding of its skin) it must go through in order to increase in size. Upon hatching from its egg, the insect is in instar I and is so called until it molts; then it begins instar II, etc.

INTEGRATED PEST MANAGEMENT (IPM)

A process for selecting strategies to manage forest pests in which all aspects of a pest-host system are studied and weighed. A basic principle in the choice of strategy is that it be ecologically compatible or acceptable.

INVERTEBRATE

Major group of animals, of which arthropods are members, characterized by the lack of **a** spinal column.

IPM

(see INTEGRATED PEST MANAGEMENT).

LAND MANAGEMENT PLANNING

The process of organizing the development and use of lands and their resources in a manner that will best meet the needs of people over time, while maintaining flexibility for a combination of resources for the future.

LARVA (plural LARVAE)

An insect in the earliest stage of development after it has hatched and before it changes into pupa, caterpillar, maggot, or grub.

LATE LARVAE

Mature larvae near the end of the feeding period; usually fifth or sixth instars in the case of budworm or tussock moth.

LEADER

Terminal, topmost shoot on a tree.

LONG-TERM PRODUCTIVITY

The capability of the land to support sound ecosystems which produce resources such as forage, timber, wildlife, and water.

LOWER CROWN

That portion of the tree crown whose main branches originate from the lower third (usually) of the tree crown.

LOWER CROWN SAMPLING

Method of estimating an index of population density of an insect by the nondestructive sampling of 18-in branches in the lower crown of trees.

LESION

An abnormal change in structure of an organ or part due to injury or disease; the affected area is generally circumscribed and well defined.

MANAGEMENT CONCERN

Any factor which is viewed by management as being detrimental.

MANAGEMENT DIRECTION

A statement that includes: Multiple use and other goals and objectives, their associated management strategies, and standards and guidelines for attaining them.

MANAGEMENT PRACTICE

A specific action, measure, course of action, or treatment.

MANAGEMENT STRATEGY

Management practices and intensities selected and scheduled for application on a management area to attain multiple use and other goals and objectives.

MASS EROSION

A general term for any of the variety of processes by which large masses of earth material are moved downslope by gravitational forces. These movements can happen very quickly or may occur over a period of years.

MATURE TIMBER

Trees that have attained full development, particularly in height, and are in full seed production.

MATURITY

The stage at which a tree or stand best fulfills the (main) purpose for which it was maintained.

MESIC

Sites or habitats characterized by intermediate moisture conditions; that is, neither very wet nor very dry.

MIDCROWN

Portion of the tree with branches originating from the middle third (usually) of the crown.

MICROCLIMATE

The climate of a small area, especially in regard to significant differences from the general climate of the region. For example, the climate under a plant or other cover, differs in extremes of temperature and moisture from the climate outside that cover.

MODEL

Formal description that represents a system or process.

MOLT

Shedding of the larval integument, a process that allows for growth.

MONITORING

A process used to collect significant data from defined sources to identify departures or deviations from expected plan outputs.

MYCELIUM

Fungal vegetative structures; usually tubular filaments.

MYCORRHIZA (plural MYCORRHIZAE)

A symbiotic or non-parasitic association between the root or rhizome of a green plant and a fungus. Also, the structure produced by the combination of the modified rootlet in conjunction with fungal tissue.

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 the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality.

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."

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.

NATURAL REGENERATION

Renewal of a tree crop by self-sown seed.

NEPA

(see NATIONAL ENVIRONMENTAL POLICY ACT).

NFMA

(see NATIONAL FOREST MANAGEMENT ACT).

NONTARGET ORGANISMS

Those organisms that inhabit a treatment area in addition to a given pest species being treated.

NOXIOUS WEEDS

Species of plants that cause disease or are injurious to crops, livestock, or land.

NPV

(see NUCLEOPOLYHEDROSIS VIRUS)

NUCLEOPOLYHEDROSIS VIRUS (NPV)

Virus which causes diseases in insects, mainly larvae of certain Lepidoptera and Hymenoptera; it is characterized by the formation of polyhedra in the nuclei of infected cells and is usually fatal.

OBJECTIVE

A concise, time-specific statement of measurable planned results that respond to pre-established goals. An objective forms the basis for further planning to define the precise steps to be taken and the resources to be used in achieving identified goals (36 CFR 219.3).

OLD GROWTH

An old-growth stand is defined as any stand of trees (10 acres or greater in size) generally containing the following characteristics: 1) Stands contain mature and overmature trees in the overstory and are well into the mature growth stage; 2) stands will usually contain a multi-layered canopy and trees of several age classes; 3) standing dead trees and down material are present; and 4) evidence of human activity may be present; but it does not significantly alter the other characteristics and would be a subordinate factor in a description of such a stand.

OLD-GROWTH STAND

(see OLD GROWTH)

OLEORESIN EXUDATION PRESSURE

Pressure within resin ducts in some conifers.

OPERATIONAL SUPPRESSION

(see SUPPRESSION AND SUPPRESSION PROJECT)

OVERSTORY

The portion of trees in a forest of more than one story, which forms the uppermost layer of foliage.

OUTBREAK

Period of high insect numbers, relative to normal population levels, in which conspicuous defoliation tree mortality or topkill occurs.

PARASITE

An animal that at some time lives in or on the body of another animal (its host), and feeding on the tissues of its host. Most insect parasites of other insects kill their host.

PARTIAL CUTTING

Tree removal other than clearcutting; that is, taking only part of the stand.

PATHOGEN

Any microorganism that can cause disease.

PEAK FLOW

The maximum streamflow in a defined period of time. Generally this period of time is a "runoff year" which runs from October 1 through the following September 30.

PESTS

Insects, microorganisms, nematodes, and atmospheric pollutants and other noninfectious disease causing agents considered to be detrimental to achieving resource management objectives.

PESTICIDE

Any substance or mixture of substances intended to prevent, destroy, repel, or mitigate any pest.

PHENOLOGY

Observational science dealing with the time of appearance of periodic events in the life cycle of organisms, particularly as these events are influenced by local conditions.

PHEROMONE

A substance secreted by an organism that causes a specific reaction in a receiving organism of the same species.

PHOTOSYNTHESIS

Process in green plants of conversion of carbon dioxide and water to carbohydrates and oxygen by using sunlight.

PHYTOPHAGOUS

Feeding upon plants.

PILOT TEST

A test of the efficacy of a pesticide against its target organism over a fairly large area before the pesticide is used operationally.

PIONEER SPECIES

A plant capable of invading bare sites (e.g., a newly exposed soil surface) and persisting there ("colonizing" them), until supplanted.

PITCH TUBE

A tubular mass of resin that forms on the surface of the bark at bark beetle entrance holes.

PLANNED IGNITION (see MANAGEMENT IGNITED FIRE, PRESCRIBED FIRE)

A prescribed fire intentionally planned and ignited by management.

PLANT ASSOCIATION

A "climax" plant community containing a definite plant composition, having a similar overall appearance, and growing in uniform habitat conditions. It is named by the climax dominant species followed by a subordinate species of a lower vegetative layer.

PLANT COMMUNITIES

Any grouping of plants recognized by an investigator as having structural similarity.

PLANT COMMUNITY TYPE

A seral stage of a plant association.

PLANT SUCCESSION

The unidirectional change in species composition resulting from the replacement of one community with another toward some stable end point.

POLE

A term used to describe young trees from the time their lower branches begin to die, up to the time when the rate of height growth begins to slow down and crown expansion becomes marked.

POPULATION DYNAMICS

The study of population numbers changes and their causes.

PRECOMMERCIAL THINNING

Any type of thinning that takes place in a stand of trees before the size or condition of the material cut or killed makes it of sufficient value to meet the costs of the activity.

PREDATOR

A free-living organism that feeds on other organisms.

PRESCRIPTION (SILVICULTURAL)

The formal written plan of action to carry out a silvicultural treatment of a forest stand to achieve specific objectives.

PRETREATMENT, POSTTREATMENT

Before and after treatment (usually used in reference to insecticide applications).

PREVENTION

Process of reducing, usually through forest management activities, the potential or severity of insect or disease problems, in order to achieve the resource management objectives for a given management unit.

PROBABILITY

A number expressing the likelihood of a specific event to occur.

PROGNOSIS GROWTH AND YIELD MODEL

A computer model for projecting growth and yield for specified management intensities.

PUPA (plural PUPAE)

The immobile, transformation stage in the development of an insect. Examples of insects with pupal stages include beetles, flies, moths, and wasps.

RECREATION OPPORTUNITY

An opportunity for a user to participate in a preferred activity within a particular setting.

REFORESTATION

The natural or artificial restocking of an area with forest trees; most commonly used in reference to artificial restocking.

REGENERATION

The renewal of a tree crop, whether by natural or artificial means. Also the young crop itself.

REGENERATION CUTTING

Any removal of trees intended to assist regeneration already present or to make regeneration possible.

REGIONAL CLIMATE

Long-term weather averages over a large area.

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. Rehabilitation is frequently accompanied by site preparation practices. The objectives of these management activities usually are numerous and may include: 1) Clearing logging slash or other debris to reduce fire hazard; 2) reducing temporarily the habitat of tree-damaging animals; 3) preparing mineral soil seed beds; 4) reducing compaction or improving drainage of surface and upper soil horizons; 5) creating more favorable microsites on harsh sites; 6) management of insect and disease problems; and 7) providing better access for planting crews.

REINVASION

The movement of an organism from one population back into an area where the organism had been excluded previously.

RESIDUAL

Remaining. Usually means those trees left after a harvest operation or a fire.

RESIN CANAL

An intercellular duct lined with cells that secrete resin.

RESINOSIS

Abnormal exudation of resin from conifers or abnormal impregnation of conifer tissue with resin.

RESOURCE

Anything which is beneficial or useful--be it animal, vegetable, mineral, a location, a labor force, a view, an experience, etc. Resources, in the context of Forest Health and Land Use Planning, thus include such commodities as timber and minerals, and such amenities as scenery, scenic view points, and recreation opportunities.

RESOURCE ALLOCATION

The action of apportioning the supply of a resource to specific uses, or to particular persons or organizations.

RESOURCE MANAGEMENT PLAN

A plan developed prior to a Forest Plan that outlines the activities and projects for a particular resource element independently of considerations for other resources. Such plans are superseded by Forest Plans.

RESURGENCE

The growth of a population back to pretreatment levels from a resident population.

RIPARIAN

Pertaining to areas of land directly influenced by water. Riparian areas usually have vegetative or physical characteristics reflecting this water influence.

RIPARIAN AREA, RIPARIAN HABITAT

That portion of a watershed or shoreline influenced by surface or subsurface waters, including stream or lake margins, marshes, drainage courses, springs, and seeps.

RIPARIAN VEGETATION

Nonaquatic vegetation found within riparian areas. Typically, this vegetation is dependent upon a seasonal high water table.

RIPARIAN ZONES

The transitional zone located between the terrestrial and aquatic zones. This stream-adjacent area contains plants, animals, and soil types specific to this area.

RISK

The probability of an undesirable event occurring within a specified period of time. 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).

ROOT DISEASE

The result of a pathogen, usually a fungus, invading roots and killing tissues or disrupting their normal function.

SALVAGE CUTTING, SALVAGE LOGGING

Harvesting of trees that are dead, dying, or deteriorating before their timber becomes worthless in an economic sense.

SANITATION/SALVAGE

The process of utilizing risk-rating systems to identify the most vulnerable insect host trees, and then removing those trees from the stand to reduce food opportunities for insects, salvage values before they are damaged, and provide a high degree of protection for the rest of the stand.

SCENIC AREAS

Places of outstanding or matchless beauty which require special management to preserve these qualities. One may be established under 36 CFR 294.1 whenever land possessing outstanding or unique natural beauty warrants this classification.

SECOND GROWTH

Forest growth that has come up naturally after some drastic interference with the previous forest growth (e.g., cutting, serious fire, or insect attack).

SEDIMENT

Earth material suspended in, or transported and deposited by, water.

SEED SOURCE

The locality where a seed lot was collected. If the stand from which collections were made was from non-native ancestors, the original seed source of a site should also be recorded and designated as provenance.

SEED TREE

A tree purposely left standing after harvest, for the purpose of producing seed for regeneration of trees in the cut-over area. It may also be a tree selected, and often reserved, to be a source of seed for collection.

SEED TREE CUTTING

Removal, in one cut, of the mature timber from an area, except for a small number of seed bearers left singly or in small groups.

SELECTION CUTTING

Periodic removal of trees (particularly mature trees), either singly or in small groups.

SEMIOCHEMICALS

Chemicals that mediate interactions between organisms.

SERAL

A biotic community that is in an early developmental, transitory stage in an ecological succession.

SERAL SPECIES

A plant species characteristic of an early stage in the development of a forest community; not permanent (see CLIMAX).

SERIES

A grouping of plant associations based on common climax dominant life form species (e.g., grand fir series is composed of all communities that when projected to an end point will have grand fir the dominant and self perpetuating component.

SEROTINOUS

Late in opening. In cones of lodgepole pine, it means having mature seed enclosed for a year or more in resin-sealed scales which require heat (fire) in order to open and disseminate.

SHADE-TOLERANT SPECIES

Plant species that grow well in shade.

SHADE-INTOLERANT SPECIES

Plant species that require plenty of light to survive and grow.

SHELTERWOOD

The cutting method that describes the silvicultural system in which the old crop (the shelterwood) is removed in two or more successive cuttings in order to provide a source of seed and/or protection for regeneration. The first cutting is ordinarily the seed cutting, though it may be preceded by a preparatory cutting, and the last is the final cutting. Any intervening cutting is termed removal cutting. An even-aged stand results.

SILVICULTURE

The theory and practice of controlling the establishment, composition, constitution, and growth of forests.

SILVICULTURAL CONTROL

Any activity involving the manipulation of stands and forests in terms of their establishment, composition, constitution, and growth in order to improve the relative susceptibility of stands to insects or diseases, and to utilize and reinforce natural regulating mechanisms for long-term protection.

SIMULATION

A mathematical representation of physical realities.

SINGLE-TREE SELECTION

Removal of individual, usually high-risk, mature trees from an even-aged forest to realize the yield and establish a new crop of irregular constitution.

SITE CLIMATE

Regional climate modified by the slope, aspect, elevation, and edaphic characteristics at a particular site.

SITE INDEX

A measure of the relative productive capacity of a site based on the heights of dominant trees in a forest stand at an arbitrarily chosen age.

SITE PRODUCTIVITY

Production capability of specific areas of land to produce defined outputs such as AUMs, cubic feet/acre/year, etc.

SLASH

The woody material left on the ground after a management activity (usually a silvicultural activity). It includes unused logs, uprooted stumps, broken or uprooted/damaged trees, branches, twigs, leaves, bark, and chips.

SLOPE

An expression of ground inclination in terms of a ratio of horizontal to vertical distance. The face of an embankment or cut section.

SNAG

A standing dead tree.

SOCIOECONOMIC

Pertaining to, or signifying the combination or interaction of, social and economic factors.

SOIL

The unconsolidated mineral and organic material on the immediate surface of the earth.

SOIL FERTILITY

The degree of ability of a soil to provide compounds, in adequate amounts and in proper balance, for the growth of specified plants.

SOIL STRUCTURE

The arrangement of primary soil particles into compound particles or clusters that are separated from adjoining aggregates and have properties unlike those of an equal mass of unaggregated primary soil particles.

SOIL TEXTURE

The relative proportions of the various size groups of individual soil grains in a mass of soil. Specifically, texture refers to the proportions of sand, silt, and clay.

SPORE

Any small cell that can regenerate into a new individual.

STAMINATE BUD

Structure that forms the male, pollen-producing cone in conifers.

STAND

Timber possessing uniformity as to type, age class, risk class, vigor, size class, and stocking class.

STAND COMPOSITION

The representation of various tree species in a stand.

STAND DENSITY

Quantitative measure of tree stocking, usually expressed as number of trees, basal area, or volume per unit area.

STAND STAGNATION

Tree growth slowed or almost stopped because of overcrowding and competition for sunlight, nutrients, and moisture.

STAND STRUCTURE

Qualitative measure of tree crown strata or height-class structure of a stand. Usually referred to by the number of canopy layers or stories represented.

STAND VIGOR

An expression, usually not quantitatively defined, of the general health of a stand. Some quantitative systems for measuring vigor exist (e.g., the Waring-Pitman Vigor-rating System, etc.).

STOCKING

In a forest, a more or less subjective indication of the actual number of trees as compared to the desirable number. More precisely, a measure of the proportion of an area actually occupied by trees.

STOCKING LEVEL

A measure of the existing number of trees in a stand in relation to the number desired for optimum growth and volume.

STRATEGY

A carefully planned course of action.

STRIP-KILL

A term used for individual trees attacked by bark beetles, it signifies a portion of the bole successfully infested by a beetle brood, usually along one side of the tree.

SUBCLIMAX

The stage in plant succession immediately preceding climax.

SUBMERCHANTABLE

Material from non-commercial activities that is below merchantability standards because of diameter size or other factors.

SUBSURFACE WATER FLOW

The movement of subsurface storm water within soil layers or above impermeable layers at a rate more rapid than usual groundwater flow.

SUCCESSION

The gradual replacement of one community of plants by another. Succession is termed primary (by pioneer species) on sites that have not previously borne vegetation and secondary after all or part of the original vegetation has been replaced.

SUCCESSIONAL STAGE

A stage or recognizable condition of a plant community which occurs during its development from bare ground to climax.

SUITABLE FOREST LAND

Land to be managed for timber production on a regulated basis.

SUPPRESSION

Action resulting from an evaluation of options that can be taken to manage insect or disease populations to achieve resource management goals. Usually, suppression takes two forms: Direct and indirect. Direct suppression means taking action directly against a pest to reduce its population (e.g., spraying insecticides, using prescribed fire, releasing parasites or predators, etc.). Indirect suppression is similar to prevention since it involves altering conditions that foster a pest population growth, thereby causing a decline in numbers. Indirect suppression methods are applied to existing pest populations with the intent of limiting damage to tolerable levels.

SUPPRESSION PROJECTS

Projects administered by the USDA Forest Service, in cooperation with State or other Federal agencies, designed to reduce high insect or disease populations in high-value or high-use areas.

SUSCEPTIBLE

The probability that trees, because of condition, species, age, or disturbance, will become infected, attacked, and damaged by insects and diseases.

TECHNOLOGY TRANSFER

Communication of research and development information to potential users that results in a change or improvement in procedure.

THERMAL COVER

Vegetation that provides wildlife with shelter from climatic conditions.

TERPENE

General name of hydrocarbons having the formula $C_{10}H_{16}$, many of which occur in volatile oils of plants.

THINNING

A felling made in an immature tree crop or stand in order to accelerate diameter increment or improve the form of remaining trees.

THRESHOLD DEVELOPMENT TEMPERATURE

Critical temperature above which some biological process, such as growth, begins.

TIMBER PRODUCTION

The purposeful growing, tending, harvesting, and regeneration of regulated crops of trees to be cut into logs, bolts, or other round sections for industrial or consumer use. For purposes of this definition, the term "timber production" does not include production of fuelwood.

TOLERANCE

Ability of an organism or biological process to exist under a given set of environmental conditions. For trees, tolerance often is associated with shade, or the ability of trees to grow satisfactorily in the shade of, and in competition with, other trees.

TOLERANT SPECIES

(see SHADE-TOLERANT SPECIES)

TOPKILL

Death or dieback of a leader and same portion of the upper part of a crown.

TOXIC

Relating to a harmful effect on the human body caused by a poisonous substance through physical contact, ingestion, or inhalation.

TOXICITY

Poisonous quality, especially its degree or strength.

TRANSLOCATION

Movement of dissolved substances through the vascular tissue of a plant.

TRUE FIR

Those species of trees such as white fir, grand fir, and subalpine fir located on mid- and high-elevation soil sites.

TUSSOCKOSIS

An allergic dermatological reaction to urticating hairs from larvae, cocoons, egg masses, or the body of the adult Douglas-fir tussock moth.

UNDERSTORY

Vegetation growing under a higher canopy; generally, small trees and woody species growing under the main tree canopy.

UNDERBURN

A type of prescribed fire, burning under a live tree overstory, intended to meet specific management and/or resource objectives.

UNEVEN-AGED

Said of a forest, crop, or stand composed of intermingling trees that differ markedly in age.

UNPLANNED IGNITIONS (see NATURAL FIRES, PRESCRIBED FIRE)

A fire resulting from a natural source (usually lightning).

URTICATING

Causing an irritation to the skin; as in the allergic reaction to tussock moth hairs, called tussockosis.

USDA

United States Department of Agriculture.

VECTOR

Insect spread of disease-causing pathogens.

VEGETATIVE BUDS

Buds that give rise to roots, stems, or leaves, and not to reproductive parts such as flowers.

VERTEBRATES

Those organisms having a spinal column protected by bone or cartilage.

VIEWSHED

The total landscape seen, or potentially seen, from a travel route, use area, or water body.

VISUAL QUALITY OBJECTIVE

A combination of inherent scenic quality and public interest which defines the acceptable degree of alteration for any given area.

VISUAL RESOURCE (FOREST SCENERY)

The composite of basic terrain, geologic features, water features, vegetative patterns, and land use effects that typify a land unit and influence the visual appeal the unit may have for visitors.

VULNERABLE (VULNERABILITY)

Probability that damage will occur in a stand, given an infestation of an insect species.

WATER HOLDING CAPACITY

The capacity or ability of a soil to hold water. Field capacity is the amount of water held against gravity or 1 atmosphere of tension. Expressed as inches of water per foot of soil depth.

WATERSHED

The entire land area that contributes water to a drainage system or stream.

WILDERNESS

Lands designated by law as wilderness; no road building or timber harvesting is allowed on such lands; they are intentionally managed to maintain their primitive character.

WILDFIRE

Any wildland fire that does not meet identified management and/or resource objectives. Such fire requires appropriate suppression response.

WINDTHROW

Trees uprooted by wind.

XERIC

A dry soil moisture regime. Some moisture is present, but it does not occur at optimum levels for plant growth. Irrigation or summer fallow is often necessary for crop production.

XYLEM

Woody tissue of higher plants, which functions to support the plant and conduct water.