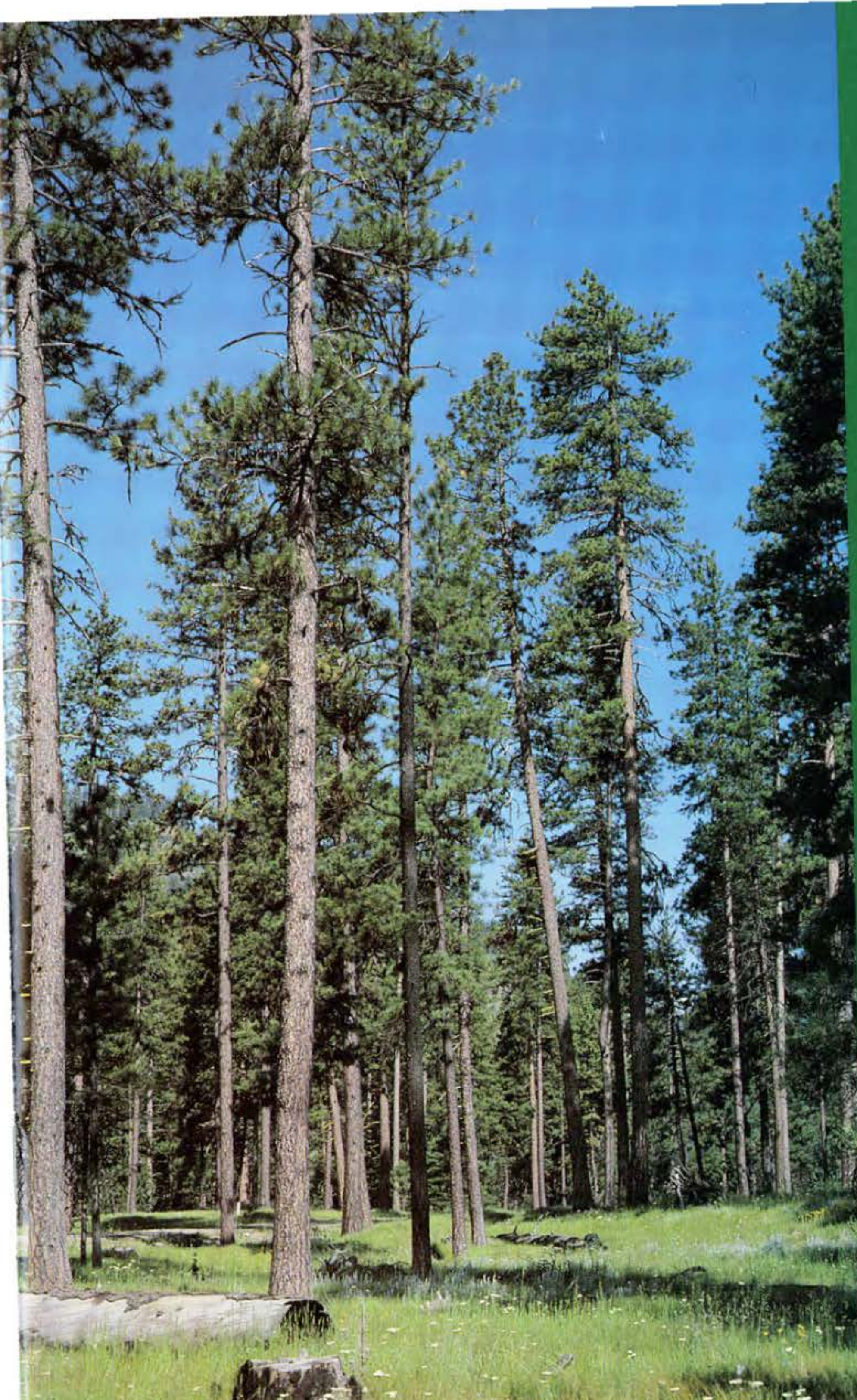

Forest Health and Ecological Integrity in the Northern Rockies

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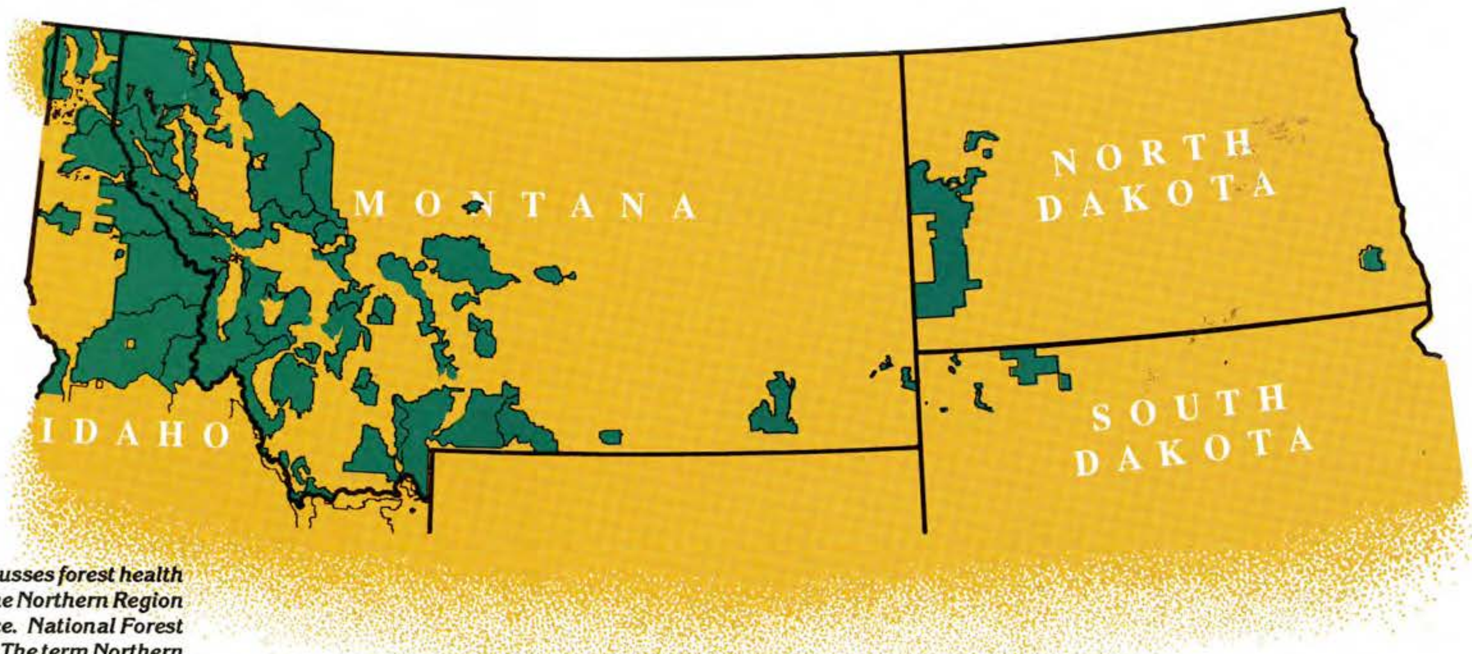
Forest Service

Northern Region



This document discusses forest health and ecological issues in the Northern Region of the USDA Forest Service. National Forest areas are shown in green. The term Northern Rockies is relative to U.S. geography and refers to those areas in northern Idaho and western and central Montana that are east and west of the continental divide.

INTRODUCTION

On a lodgepole pine tree in a northwest Montana forest, a small beetle begins to burrow through the bark. The beetle, about twice the length of the letter "l", rivals the biblical David in its choice of targets. The beetle has picked one of the largest pines in the stand, a tree that has stood against the wind and weight of snow for 120 years. This is old growth in the world of lodgepole.

As the burrowing continues, the tree begins its defense. Resin oozes from the bark. If the tree is healthy, if it has not been stressed by drought, competition, or repeated attack, its resin will wash the beetle out. If the tree is weak, the beetle will penetrate the bark in several hours. There she will emit a pheromone, a chemical signal, that alerts other females and males that a weakened tree can be overcome. Galleries are carved beneath the bark, and eggs are laid. Well before the beetles emerge the following year, the tree is effectively dead.

The record of beetles preserved in amber, the crystallized resin of trees, shows that this battle between host and insect has been ongoing for thousands of years. Within the last one hundred years in this country we have institutionalized the concept of forest management. Our challenge is to integrate this forest management with functioning ecosystems that have been self-sustaining for millennia.

A key element in the modern practice of forest management is the protection of forests. Protection efforts have, at times, been herculean. We have fought fires with everything from shovels to slurry bombers. We have pulled Ribes bushes from millions of acres to protect white pine from blister rust. We have sprayed biological and chemical insecticides over large areas to prevent tree defoliation. Often we have succeeded in protecting trees from damage. Indeed, some argue that we have been too successful, that we have protected trees at the expense of the forest and its long term health. We are encouraged to take a broader perspective.

Annually the Northern Region of the Forest Service issues reports on the incidence of insects and disease on forest lands, primarily in northern Idaho and Montana. The statistics, as shown in part below, can be impressive whether expressed in millions of acres or billions of board feet. Should the numbers concern us? Should we intervene? Are these problems or parts of natural cyles? These are some of the questions addressed in the following discussion.

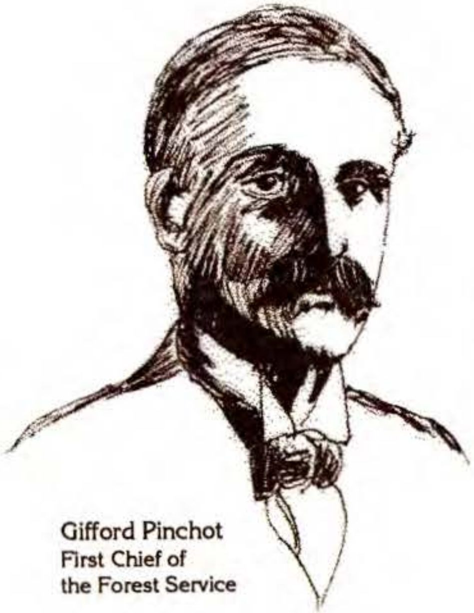
A bark beetle preserved in amber for about 2 million years. Very similar in form and function to the many species of bark beetles now inhabiting the Northern Rockies.

Amber photo courtesy Dr. Stephen L. Wood and John Anhold

Examples of Insect and Disease Impacts on Forests of the Northern Region

Mountain Pine Beetle	Root Disease	Western Spruce Budworm	Dwarf Mistletoes
Betwen 1970 and 1990 approximately 3 million acres of forest were affected. Mortality estimated at 240 million trees, generally the largest and oldest trees on site. Average annual mortaility equivalent to 600 million board feet.	Root diseases are affecting more than 3 million acres of commercial forest land of various types. Impacts include a reduction in timber volumes by nearly half.	Between 1 and 4.5 million acres are visibly defoliated each year. Stands with multi-year, visible defoliation show a 25% reduction in tree growth, widespread understory mortality, and a predisposition to bark beetle attack.	Dwarf mistletoes occur on about 3.5 million acres of commercial forest land. They cause about 250 million board feet of growth loss each year.

FOREST MANAGEMENT AND FOREST HEALTH



Gifford Pinchot
First Chief of
the Forest Service

Our goal is healthy forests. In the abstract this goal has universal appeal. Yet defining the healthy forest can reveal much about our value systems and our views on forest management.

Two perspectives of forest management have loomed large in the history of the National Forest System from the time of John Muir and Gifford Pinchot. Let us briefly consider these perspectives and their forest health implications.

In its purest form we might call one view the agricultural perspective. Gifford Pinchot provided this viewpoint in his autobiography *Breaking New Ground*:

> *Forestry is Tree Farming. Forestry is handling trees so that one crop follows another. To grow trees as a crop is Forestry.*
>
> *Trees may be grown as a crop just as corn may be grown as a crop. The farmer gets crop after crop of corn, oats, wheat, cotton, and tobacco, and hay from his farm. The forester gets crop after crop of logs, cordwood, shingles, poles, or railroad ties from his forest, and even some return from regulated grazing...*
>
> *Farmer and forester alike get a lot of other products on the side. Good farming yields also such things as butter, eggs, apples, calves. Good Forestry, in addition to lumber, firewood, and other produce, yields such services as the regulation of stream flow, protection against erosion, and some influence on climate.*
>
> *Farming cannot go on unless crop succeeds crop. No more can Forestry. A farm crop may reproduce itself, or it may have to be sown or planted. Just so with trees...*
>
> *A well-handled farm gets more and more productive as the years pass. So does a well-handled forest.*

This statement of the agricultural perspective will strike some as single-minded and insensitive to a variety of other values. However, in its historical context this perspective contrasts with the frontier mentality that viewed forests either as an impediment to development or as a limitless resource. The perspective provides the basis of stewardship in the attitude that forests should be managed for the future. We also see in the last paragraph of Pinchot's statement the note of optimism that human intervention can improve the system.

The pure commodity approach to forestry has been modified over the years, particularly on public lands. However, the agricultural perspective continues to be reflected in the desire to reorder the system to increase productivity. Managers are called on to defend their trees against threats such as fire, insects, and disease with various technologies. These agents are seen as causing our forest health problems. Basic to this management perspective is the concept that the system can be reordered to better meet human needs.

As the discipline of forestry developed in America, the utilitarian approach was challenged. Aldo Leopold, whose career with the U.S. Forest Service began in 1909 while Gifford Pinchot was still its Chief, sought a broader perspective. He spoke of an A-B cleavage in his essay "The Land Ethic."

> *In my own field, forestry, group A is quite content to grow trees like cabbages, with cellulose as the basic forest commodity...Group B, on the other hand, sees forestry as fundamentally different from agronomy because it employs natural species, and manages a natural environment rather than creating an artificial one. Group B prefers natural reproduction on principle. It worries on biotic as well as economic grounds about the loss of species like chestnut, and the threatened loss of the white pines. It worries about a whole series of secondary forest functions: wildlife, recreation, watersheds, wilderness areas. To my mind, Group B feels the stirrings of an ecological conscience.*

Since Aldo Leopold wrote those words, the stirrings of ecological conscience have become a maelstrom that has engulfed public land management. The battles are often cast in terms of preservation versus utilization. For the forester caught between the public's demand for wood products and the protection of forest amenities, extreme positions hold little comfort.

Jerry Franklin posed the issue quite succinctly: "Is there an alternative to the stark choice between tree farms and total preservation?" His answer, phrased in terms of biodiversity, has a number of implications for forest health concerns:

We could never hope to adequately protect biological diversity solely through preservation, since so much diversity occurs on commodity landscapes, which represent vast acreage. The productivity of our land, the diversity of our plant and animal gene pool, and the overall integrity of our forest and stream ecosystems must be protected on those landscapes as well as in preserves...The stewards of our public lands—indeed of all our forestlands—need to adopt the ecosystem perspective. Doing so will finally provide a philosophical underpinning for the oft-maligned multiple-use concept. Judgments regarding timber production, recreation, and the enhancement of wildlife and wilderness will be made with our eyes clearly focused on what will best maintain resilient, diverse, and sustainable forest ecosystems. (Franklin 1989)

These perspectives on forest management form the basis for several approaches to forest health problems, particularly the management of insect and disease threats.

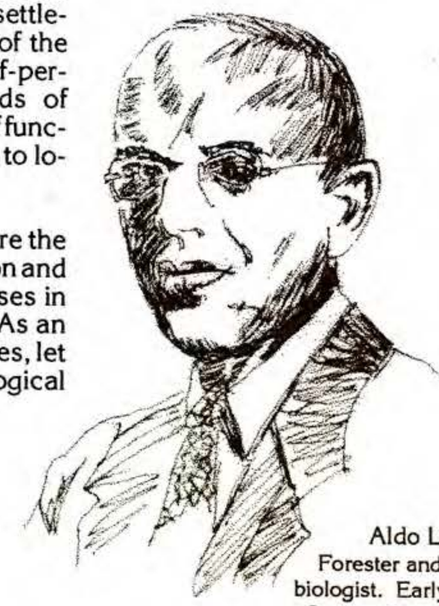
In an agricultural approach, the threat posed by insects and diseases is met head-on. Thresholds of damage are monitored and, where exceeded, direct suppression is attempted most often with technological means.

Under an ecological approach, at least two other possibilities are considered. An insect or disease outbreak could be symptomatic of an ecosystem out of balance. In a more balanced system the threat would be minimized. Management must then be adapted to restore the system.

Alternatively, in many situations forest insects and diseases play important roles in properly functioning ecosystems. These agents have been a major factor in forest development in the northern Rockies. They also provide a variety of secondary benefits to wildlife and biotic diversity by modifying the forest environment, creating habitat, and providing food sources. In these situations our management expectations may require modification to correspond to ecosystem realities.

The appropriate response to an incident will depend on the site and on the ecological context. In some situations, direct suppression of pests may be necessary. In any case, our response must be based on an understanding of ecological principles in the context of our management objectives. Part of this understanding will come from the knowledge of how these forests operated before European settlement. Because the forests of the pre-European era were self-perpetuating through hundreds of years, they provide models of functioning ecosystems adapted to local conditions.

In this publication we explore the concept of ecosystem function and the role of insects and diseases in three different forest types. As an introduction to these examples, let us briefly discuss the ecological concept of "succession."



Aldo Leopold
Forester and wildlife biologist. Early Forest Service Ranger in the southwestern U.S. Author of *A Sand County Almanac.*

FORESTS OF CHANGE

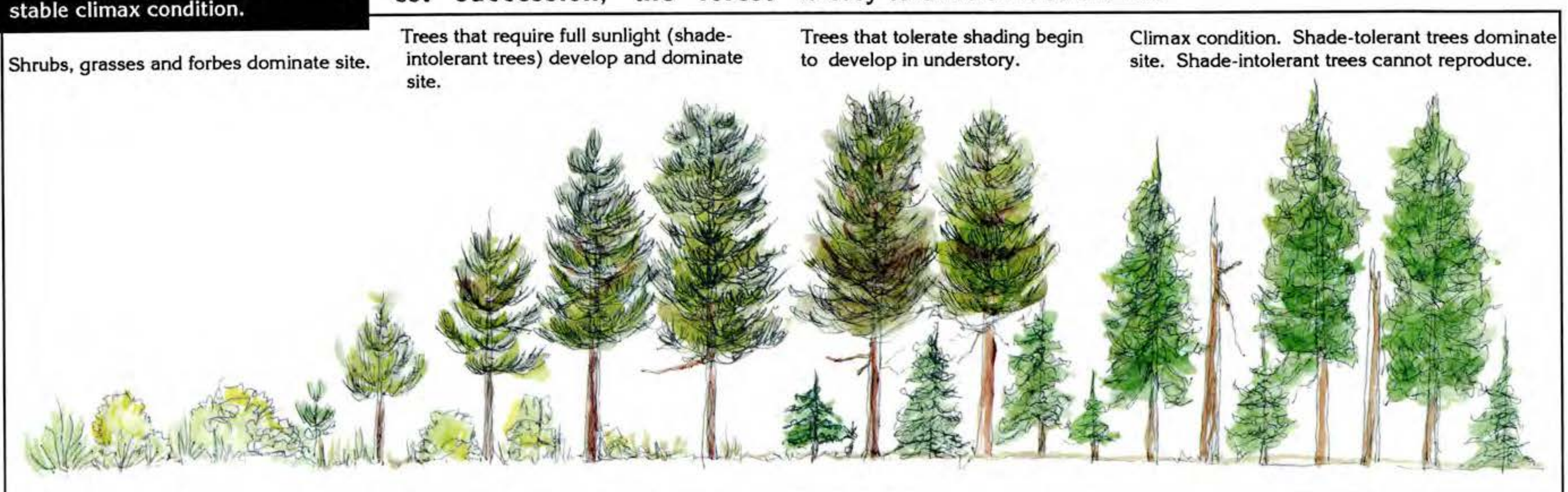
Change is fundamental to all ecosystems. The term forest succession refers to the patterns of change in vegetation over time. The concept of forest succession is so fundamental to the study of forest ecosystems that professionals often neglect to gauge the public understanding of the principle. The concept can quickly clash with the human desire to maintain stability and control the environment. We are drawn to trees in part because of their seemingly timeless quality. In a world of seething change the ancient forest becomes the symbol of venerable serenity. In such a world view, for example, the fires of Yellowstone can be seen as an aberration and not part of a natural process.

In simplified presentations of forest succession, the forest progresses toward a final or climax condition as shown in the figure below. Although details vary, several elements are commonly presented in the sequence of forest succession. Following a major disturbance, such as a stand-replacement fire, the site enters a relatively short period in which grasses, forbs, and/or brush dominate. This period is typically followed by the dominance of tree species that require open sunlight (shade-intolerant or early seral species). In a final stage shade-tolerant or climax species germinate below the shade-intolerant species and eventually dominate the site.

The climax condition is popularly conceived as the goal to which forests are progressing. It is easy to envision it as the last and best forest, the forest primeval. However, it is not necessarily the natural state of forests in the Northern Rockies.

In the Northern Rockies, many forest types rarely reached climax conditions in pre-European times because of frequent disturbances. More typical patterns of forest development are shown in the second depiction of succession. Major elements in forest succession were insects, disease, and fire amplified by periodic drought. Depending on the site, the interval between disturbances could range from a decade or less to more than a century. However, disturbance was inevitable and had an important role in maintaining these forest types.

The classic view of forest succession. In this perspective the forest progresses to a relatively stable climax condition.



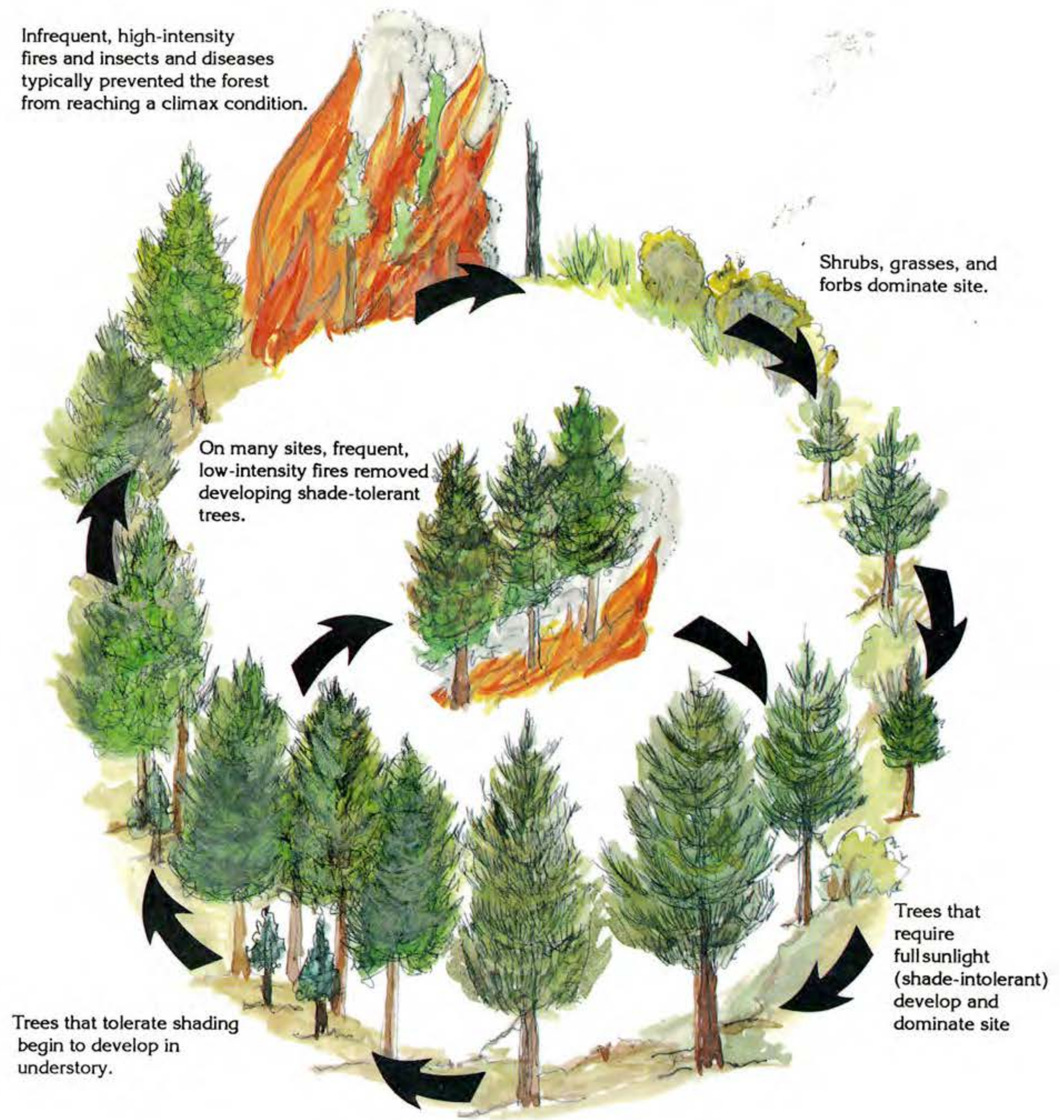
Forest succession in the Northern Rockies. Pre-European forest succession to a climax forest was often interrupted by insects, diseases, and fire.

The Northern Rockies are a fascinating place to investigate the process of forest change and forest health. We have a large number of forest types due to the variety of site conditions here. A number of tree species are living at the edge of their ranges. As with most organisms living "on the edge", these species are susceptible to a variety of stresses.

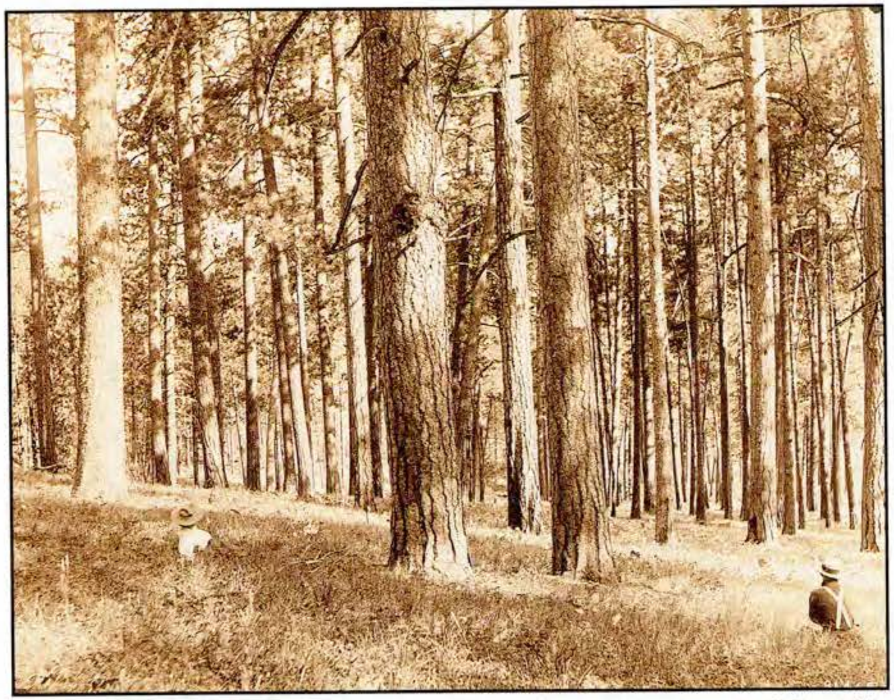
In the following sections we will examine three specific examples of forest systems under stress. Each of the three examples focuses on one aspect of insect and disease interactions with the forest environment.

The example of the ponderosa forests illustrates how insects and diseases respond to subtle changes in forest species composition and structure. The lodgepole example focuses on the role insects and diseases play in maintaining some forest types. The white pine example demonstrates how non-local phenomena such as the introduction of exotic pathogens or global events such as climate change could affect the forest ecosystem.

The case studies are necessarily brief and cannot discuss all the complex interactions of these species in their many habitats. However, the examples do illustrate some of the major forces at work in Northern Rocky Mountain forest types.



PONDEROSA PINE: THE FOREST OF THE "OLD WEST"



Lick Creek 1909.

This photo shows a mature ponderosa forest in the Lick Creek area of the Bitterroot National Forest in 1909. Analysis of fire scars indicates that surface fires burned through the area on average every 7 years between 1600 and 1900.

The scenic image of the old west has been largely crafted by movies and television. The outstretched arms of the saguaro cactus, longhorn cattle on sage-covered slopes, and open forests of ponderosa and sugar pine are the scenery of the western. The classic ponderosa forest provides an ideal outdoor movie set. Action can be filmed from a variety of angles in this open forest, and, most importantly, horses can be ridden through the widely spaced trees.

Like the cowboy who roamed there, open stands of ponderosa pine are an increasingly rare phenomenon. It is not that the tree itself is in danger of extinction. To the contrary, in some areas it can be argued that we have too many ponderosa pines. Rather it is the characteristics of the ponderosa forest that have become rare.

Comparison photos taken over time in the Lick Creek area illustrate the changes in many ponderosa forest stands since the late 1800's. We see a marked increase in the number of trees and, on some sites, a change in the mix of tree species.

The changes in this forest type are attributable primarily to two factors: the aggressive control of wildfire and some types of timber harvest. Prior to European settlement wildfire generally visited these stands of ponderosa pine every five to fifteen years. Typically, these low-intensity fires consumed only the grass, brush, and small trees of the understory. Occasionally individual or small groups of larger trees would be burnt, which would open the forest further. In these newly opened areas, seedlings could grow rapidly and possibly escape the effects of subsequent fires. For the individual tree it was a random and uncertain process. Forestwide, the results were predictable: open, parklike stands of ponderosa pine.

When wildfire is controlled, vegetation develops vigorously under the mature trees. On the driest sites inhabited by ponderosa pine, the open, well-lit forest floor may favor the development of an understory of young ponderosa pine. Slightly wetter and cooler sites favor the development of shade-tolerant Douglas-fir in the understory.

Some timber-harvesting practices have attempted to capitalize on the developing understory of small trees. When the mature ponderosa pine are removed, the remaining immature Douglas-fir can provide a headstart on a new forest. At first glance the strategy seems reasonable. It avoids regeneration costs. It avoids the stigma of clearcutting. It leaves the site looking greener. Thus this practice has been widely implemented in some areas in the west.

Lick Creek 1937

In contrast, photos taken in the Lick Creek area in the 1930's and 1940's, and later show abundant regrowth of Douglas-fir and pine as a result of fire suppression. A complete set of photo points documenting the effects of fire suppression and timber harvest over time is contained in Gruell et al., 1982.

Even in the absence of cutting, Douglas-fir will eventually dominate many of these sites as long as fire is kept from the forest. Douglas-fir can capture the site because it can grow in the shade of the ponderosa, while ponderosa seedlings require more open, sunlit conditions. The historical photographs in this section depict this trend.

These transitional forests have a number of characteristics not found in the pre-European ponderosa forests. There is greater diversity of species and tree ages and sizes. If this short-term increase in diversity is our sole measure of ecosystem integrity, then the forest may seem improved. However, this condition is not sustainable.

This shift in species and structure has other impacts. One frequently mentioned is the increased risk of a high-intensity fire.

Although fire can be kept from an area for long periods, it will return eventually. The developing understory greatly increases the likelihood that a fire will consume all the trees in the stand as the flames "ladder" from the developing understory to the forest canopy. The reservoir of fuels, that once were consumed on a regular basis by low-intensity fires, now fuel a high-intensity, canopy burn.

After a high-intensity fire the site will return to an early stage of succession typically dominated by grass. On drier sites many years may pass before the trees return to the site.

A second effect follows the replacement of ponderosa pine, a tree species that is relatively insect and disease resistant, with Douglas-fir, a species that is less resistant on these dry sites. Insect and disease outbreaks increase in many of these areas. Spruce budworm has defoliated large areas of forest newly dominated by Douglas-fir. Defoliation has been particularly severe in some parts of the Northern Rockies and in drier mountain ranges east of the Cascades in Oregon and Washington. Less obvious but possibly more destructive damage is caused by various root pathogens and dwarf mistletoe.

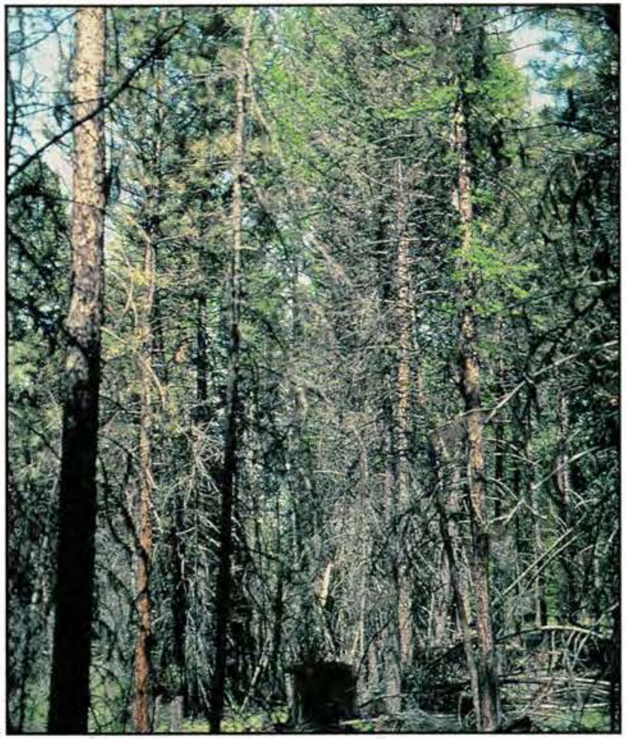
Frequent surface fires maintained open ponderosa pine forests.

In order to protect trees that represent future timber production, forest managers can consider a variety of pest suppression techniques. For example, in the west we have aerially sprayed vast acreages to combat western spruce budworm and other defoliators. In the Northern Rockies, the value of traditional direct suppression has been increasingly scrutinized. Economic analyses of the cost and benefit of such suppression techniques often does not support their use. Spray programs may only postpone and may even prolong an outbreak.

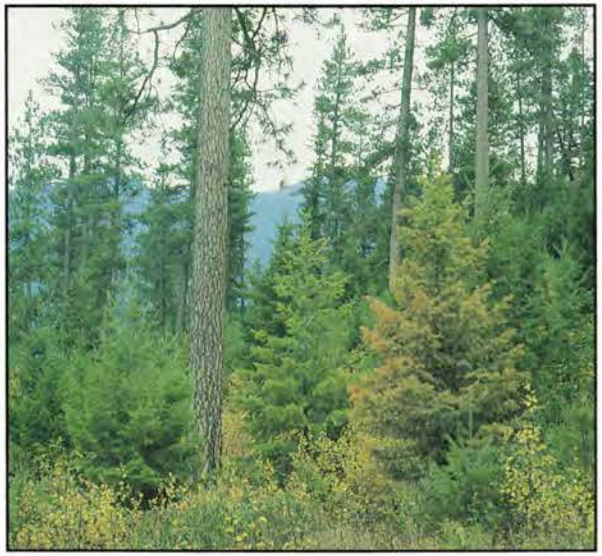
Other insects or pathogens such as dwarf mistletoe are not readily suppressed with the use of pesticides. We are fortunate, however, to have other management tools to choose from. In some areas increased reliance on prescribed fire has allowed us to return sites to a more natural condition and reduce susceptibility to tree mortality on a large scale from catastrophic fire. On drier ponderosa pine sites, harvesting of small groups of trees, rather than clearcutting greatly increases the likelihood of successful pine regeneration. This regeneration of small patches and the removal of emerging shade-tolerant species through cutting or fire can preserve park-like stands of ponderosa.

In other areas where the transition to more shade-tolerant species such as Douglas-fir is virtually complete, other treatments may be necessary. Many of these stands of trees are riddled with root pathogens, dwarf mistletoe, and periodic attack of defoliators. Removal of most if not all of these trees may be necessary to plant and restore the forest. Live trees that are infested with mistletoe or root pathogens will infect the next generation of trees if left on the site.

The alternative to restoring these forests to a species mix more resembling the pre-European condition is a forest condition that is increasingly subject to insect and disease attack and catastrophic fire. In place of a well-spaced ponderosa forest landscape, will be scrub forest whose development is continually retarded by defoliating insects and various pathogens. The photographs on this page provide several views of this condition. These "new forests" provide neither the ecological values we associate with old growth dry-land forests nor the commodity outputs we may plan from these forests.



Western spruce budworm defoliation



The Douglas-fir that is replacing ponderosa pine is very vulnerable to defoliation and mortality from spruce budworm and root disease. An estimated 15 million acres of ponderosa forest types in Idaho, Montana and eastern Oregon and Washington are similarily affected.

Root disease mortality

LODGEPOLE PINE: FORESTS OF FIRE

In the ponderosa forest types, we see examples in which insect and disease problems have increased with our management activities. The lodgepole pine forest provides a somewhat different set of circumstances. Lodgepole pine has evolved in concert with insect outbreaks that are closely tied to the success and dominance of the species in many areas. This interaction also has interesting implications for an ecological appreciation of forest health.

In a review of the characteristics of the lodgepole forest types, one ecologist has noted that the lodgepole forest will challenge anyone who would apply concepts of "climax plant communities, steady-state dynamics, ecosystem stability, or unidirectional succession (Volland 1985)." Simply put, if we seek a forest that is progressing steadily to a climax, old growth condition, we would do well to look elsewhere than in a forest of lodgepole. Indeed, the lodgepole pine has developed strategies that capitalize on and even promote short-term ecosystem instability to insure its long-term dominance on many sites in the Northern Rockies.

Lodgepole pine is frequently portrayed as living in a measured dance with its primary insect predator, the mountain pine beetle. When the stand of trees is young, the beetle poses little threat. The beetle remains at low populations, continually probing and occasionally taking a tree, often in association with other insect species such as the ips beetle. As the trees age, the inner bark or phloem thickens, and they become more suitable hosts for the mountain pine beetle. When the growth rate of the large diameter trees slows and environmental conditions are suitable, the beetle populations explode. The beetles then mass attack large numbers of suitable host trees. Extensive mortality follows, and trees become fuel.

Again the wait begins, this time for the return of dry conditions and the chance spark of lightning or other ignition source. The large number of dead trees following a mountain pine beetle infestation often ensures that fire will burn the entire stand. The results can be a firestorm, with spectacular footage for the camera. It has become the public's image of the fire that must be stopped. However, lodgepole pine has adapted to fire. A high percentage of its cones are closed with the seed protected from fire. After the cones are opened by high temperatures, the seeds are available to recolonize the site. The competition of less fire-adapted species has been reduced.

The period between such stand-replacement fires may vary from less than 100 years to as much as 350 years depending on the site. It is important to note that this simple cycle of regenerated forest, mountain pine beetle attack, and fire is highly variable with habitat characteristics. On some lodgepole sites cool fires also occurred every 20 to 50 years. As in the ponderosa pine forests such fires could reduce the shade tolerant tree species on the site. In addition, by scarring and weakening individual lodgepole pines, cool fires also aided bark beetle attack and ensured the continued existence of endemic beetle populations.

A policy of vigorous fire suppression will have significant impacts on a fire-dependent species such as lodgepole pine. In areas naturally subject to periodic underburning, fire suppression will cause fuel levels to increase. Fire suppression over the last 50 or more years has also resulted in large expanses of mature lodgepole pine. Extensive epidemics of mountain pine beetle occurred during the 1970's and 1980's in these mature lodgepole forests. On many of these sites, shade-tolerant climax species such as subalpine fir or Douglas-fir are beginning to dominate.

The critical role of fire must be accounted for in our management of lodgepole forest types. Allowing and even planning fires in forests that are allocated to wildlife, dispersed recreation, or wilderness will be necessary to create a variety of age classes. Although some might argue that wildfires can be suppressed indefinitely with modern fire-fighting technology, a dispassionate view of the fire record in these forests shows that we are only postponing the inevitable. Insects such as mountain pine beetle and serious pathogens such as dwarf mistletoe are creating forests for the burning. The situation is like holding water behind a leaky dam. We can either draw the water down gradually or we can wait for the dam to break.

On lands managed for timber production, additional challenges are emerging. Long dismissed as an inferior species, in part because of its often unimpressive dimensions, lodgepole is now valued in modern, efficient milling operations. Traditionally lodgepole has been considered relatively easy to cultivate. After harvesting and slash burning, sufficient seed often remain on the site to insure a regenerated forest.

The situation has become more complicated as we consider the management of lodgepole-dominated ecosystems. Nature can paint the lodgepole landscape with a fairly broad brush and coarse strokes. In a natural system, fire can consume hundreds or thousands of acres. By contrast our management has often focused on forty to sixty acre units, partly because of legal constraints and partly out of habit. If harvesting and silvicultural techniques are going to represent the natural forces at work in these systems, we must ask how these will be reconciled with the social and legal forces that govern forestry.

The Forest Service is under increasing pressure to find alternatives to traditional forestry techniques such as even-aged management and, specifically, clearcutting. Within the lodgepole forest there are opportunities for non-traditional management. These include leaving patches of unharvested trees and other selective harvesting techniques. However, there are limitations if our management is to stay within ecosystem successional patterns.

Mountain pine beetle can affect thousands of acres of susceptible trees. It can also create a mosaic effect on the landscape by sparing areas with younger lodgepole pine or areas with other species.

Fire creates different age classes of lodgepole pine trees that will have differing susceptiblities to insect and disease.

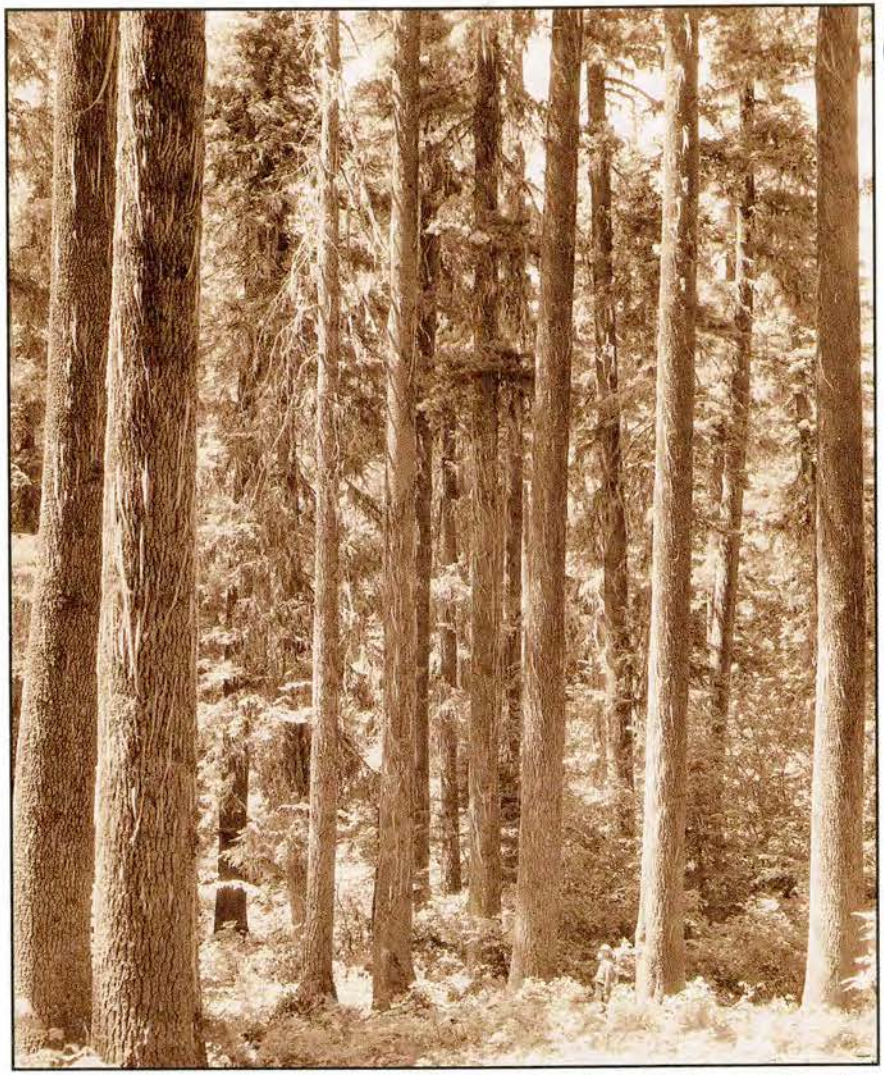
Mistletoe seriously infects nearly half the lodgepole stands in the Northern Rockies. If mistletoe-infected trees are left alive on a site after timber harvesting, they will infect newly regenerated trees within a few years. The result will be a stand of stagnating, unhealthy trees as shown in the photographs on this page. Selective cutting in these diseased stands will consign them to a degenerated condition until sanitized by stand-replacement fire or its equivalent.

The key to managing the lodgepole forest is understanding what the species can and cannot do. Lodgepole will not provide the ancient stands of majestic old growth as seen in the Pacific Northwest. Nor do we have a ready replacement for the species since lodgepole pine is uniquely adapted to prosper on millions of fire-dominated acres in the Northern Rockies. Rather, we will have to appreciate the resilience of this species that flourishes with its own demise. In the times of royalty, with the death of the monarch, the crowd would salute his heir with "The king is dead, long live the king." So it is with lodgepole.

Dwarf mistletoe causes the infected tree to form bunched branches called brooms. Growth is greatly reduced and trees may eventually die. Selective cutting in heavily infected stands will allow infected trees to spread the pathogen to young developing trees.

Fire is nature's way of removing mistletoe from a stand. Lodgepole pine has adapted to major, stand-replacement fires.

WESTERN WHITE PINE: DYSFUNCTIONAL ECOSYSTEMS



A white pine stand, typical of northern Idaho at the turn of the century. Note the human figure for perspective.

Our previous two examples have illustrated the theme that properly functioning forests proceed through cycles of succession and disturbance. If we would conserve biological diversity and ecological integrity, we must allow for these cycles. If we are to manage these forests for a variety of values and simultaneously maintain forest ecological integrity, we must represent as closely as possible these cycles with our management activities.

In addition to our direct management activities, other human-induced forces are acting on these forests. A major and little-recognized influence on native ecosystems is the introduction of exotic biological organisms.

Biological organisms have migrated at a low rate throughout the earth's evolutionary history. The movement of species increased significantly on a world-wide basis with the age of exploration and has continued through the age of world commerce and travel. European settlement of the Americas introduced many plants, animals, and diseases into new habitats. These introductions were often promoted as beneficial, and a number of important agricultural species were successfully established in the Americas. Yet many of these intentional and unintentional introductions have had a devastating effect on natural ecosystems.

Plants and animals that evolve with pathogenic organisms reach a balance with these agents; most individuals in the population develop at least a partial resistance. However, when a preadapted pathogen is introduced to an isolated, previously unexposed population, the results can be catastrophic. The introduction of small pox to American Indian tribes is an example of the devastating effects of such disease pathogens.

In addition to direct impacts such as massive population dieoffs, these exotic organisms often have less obvious secondary impacts. The organizational capacity of an affected population may be so disrupted that the system is irreversibly damaged.

In 1909 and 1910 white pine blister rust was introduced on contaminated nursery stock from Europe to the east and west coasts. Initially in the early and middle part of this century significant efforts were made to limit the spread of this pathogen. Control efforts typically involved pulling or, later, spraying Ribes bushes. The blister rust organism must spend part of its life cycle on these plants. This technique was moderately successful on the more accessible east coast lands. However, in the vast expanse of western wildlands it was an impossible task. In the west blister rust has typically killed in excess of 90 percent of the western white pine. The disease has worked in conjunction with other pressures on these forests to cause a major shift in species composition and ecosystem function.

Our knowledge of the forest conditions of the late 1800's is incomplete. Nevertheless, it is clear that northern Idaho and portions of western Montana were well-forested and contained extensive tracts of old growth coniferous forests. Stands of open, old-growth ponderosa pines covered the lower slopes. Mixed stands of subalpine fir and other conifers were present at high elevations. At mid-elevations vast areas were covered by stands of western white pine, usually mixed with western larch, grand fir and other conifers. Douglas-fir was often present, but seldom abundant. Old-growth stands of western white pine with ages of 150-350 years were common. The extensive white pine forests were considered a major resource, and brought about a western migration of Eastern sawmill owners who were running out of valuable eastern white pine.

As in the previous examples of ponderosa and lodgepole forest types, fire once maintained important forest characteristics. Periodic, low-intensity fires burned through the white pine forests, killing understory Douglas-fir and other fire-susceptible tree species. Some larger white pine could also be killed by these fires. As the white pine developed into old-growth stands, it became more susceptible to insects, particularly mountain pine beetle. Increasing volumes of dead wood led to infrequent, high-intensity, stand-replacement fires during periods of drought and high winds.

Various diseases also were agents of change. Root disease fungi thinned the mixed conifer stands and shifted species composition toward western white pine and western larch by selectively killing the more susceptible Douglas-fir and true firs.

In the past century we have seen in the white pine forests many of the same human-induced changes that occurred in the ponderosa pine forest types. Fire control and selective cutting of high-value western white pine favored the more shade-tolerant Douglas-fir and true firs. Mixed stands still cover the white pine zone, but Douglas-fir is now the major species. Western white pine, when present, is seldom abundant—the reverse of the past. The white pine blister rust fungus virtually eliminated reproduction of this key species from northern Idaho stands where it once was abundant.

The prevalence and role of various insects and diseases changed when the forests changed. Mountain pine beetle has become less common in these areas with the loss of the white pine. Root diseases and Douglas-fir beetles are now the major agents of change in the Douglas-fir and true fir stands.

In 1910 and in the 1920's and 1930's wildfire burned millions of acres in northern Idaho and western Montana, much of it covered with white pine. Many areas burned 2 or 3 times.

Because of their susceptibility to root diseases, Douglas-fir and the true firs are poor substitutes for white pine as the dominant species in these forest types. Annual Douglas-fir mortality from root diseases is significant long before the forest matures. Over time pockets of disease expand, as shown in the accompanying photo. The end point of succession now appears to be root-disease-infested patches of brush and susceptible trees that succumb to these pathogens before reaching maturity.

On sites allocated for timber harvest, the timber productivity has been reduced by about one-half. Further reduction in the future is expected if a second rotation of Douglas-fir follows the current rotation.

Wildlife populations are also affected. Although deer and elk may profit from the creation of brushfields, we can assume that a variety of old growth-dependent species have suffered from the loss of the white pine forests. Without a clear picture of the character of the original white pine forest, the extent of these changes can only be surmised.

Restoring these ecosystems will require intensive effort. It is fortunate that western white pine shows a low level of natural resistance to blister rust. Selective breeding programs by the Inland Empire Tree Improvement Cooperative has increased the rate of resistance among nursery stock. However, blister rust is an elusive foe that can adapt to overcome resistance. Thus the plant geneticist must cultivate a variety of resistance mechanisms to insure continued resistance.

The story of the white pine blister rust is an example of the influence of non-local, even global phenomena on local forest conditions. These influences include not only exotic species but also the potential impacts of climatic variation, the global spread of some pollutants, and atmospheric changes. Unlike many of our forest management activities, we often do not have local control over these influences.

Forest managers will be required to go beyond a purely reactive response to global influences. Part of the task will be to understand the nature of these influences and to assist in limiting their proliferation, if necessary. Part of the task will be to understand better the proper functioning of our forest systems. Our forests are in a continual state of flux. We must now better understand the proper limits, for an acknowledgment of the reality of change in forest systems is not an acquiescence to all possible change.

***Blister rust** has killed most of the white pine as it attempted to regenerate in burnt or harvested areas. The green trees in the foreground are grand fir, unaffected by blister rust. Grand fir and Douglas-fir replaced white pine on most of these sites.*

***A root disease patch.** Root disease has killed most of the trees, creating an opening. These diseases often spread outward from a center through root contact between trees. Douglas-fir and grand fir are particularly susceptible in the Northern Rockies, and several million acres are adversely affected.*

MEASURES OF FOREST HEALTH

Charlotte Peak burn area: Bob Marshall Wilderness

Timber harvest: Helena National Forest

Forest managers will be continually challenged to make commodity-producting activities more closely represent natural processes.

The three examples of forests under stress illustrate some of the complexities in managing for healthy forests. The question remains: How do we judge the health of a forest? Several criteria are possible.

We can consider our management objectives for a tract of forest. A forest could be classed as healthy if various biological and physical influences do not threaten present or future management objectives. This definition can focus on forest outputs, but these need not be defined only in terms of commodities such as timber or livestock. Management objectives can be expanded to include wildlife, clean water, biological diversity, and other uses, values, and outputs.

A second set of criteria for forest health focuses on ecosystem function. A forest in good health is a fully functional community of plants and animals and their physical environment. A healthy forest is an ecosystem in balance. Yet the concepts of ecosystem balance and function are difficult to define in the absence of a model. We have indicated the pre-European condition as a possible standard for our efforts. We have also indicated that this condition was not static. We must be more interested in forest processes than in any final condition.

Aldo Leopold implicitly acknowledged the connection between health and forest succession in his definition of health as "the capacity of the land for self-renewal." By this definition the health of the forest is best be measured in its patterns and rates of change compared to historic patterns. Ecosystem balance, in this perspective, is the balance of a bicycle rider in motion.

Neither set of forest health criteria is entirely independent. Our judgement of forest health will be a compliment of ecosystem function and management objectives. To be successful over the long term, management objectives—whether they involve commodity production or amenities such as scenic landscapes—must reflect ecosystem limitations.

In some cases our forests have crossed ecological limits, and severe outbreaks of insects and pathogens have been a signal. The forests of the Northern Rockies have generally responded poorly to the effects of fire suppression, the introduction of exotics such as blister rust, and some silvicultural techniques. Some effects of these changes are easily measured, such as impacts on tree growth and timber volume. Other impacts on nutrient cycling, wildlife habitat dynamics, and hydrologic cycles have been only partially explored.

An ecosystem approach is complicated by changes in our forests since the early settlement days and by an inability to fully define pre-European conditions and processes. The changes in our forests over the past century and the current societal demands on our forests make duplication of the pre-European condition a virtual impossibility—even in areas reserved from commodity production. The quest for healthy, sustainable forests will require numerous approximations and continual monitoring of effects.

Humans will have a more active role in the management of these forests than at any point in the past. Human agendas and objectives will be apparent, but we must expand our understanding of these systems to a level commensurate with our demands on these forests. The health of our future forest will depend on a management activities that foster the natural structure, composition, and function of our ecosystems.

THE PATH FROM HERE


Foresters in a white pine stand, early 1900's

We began with the recognition that insects and disease are important elements in the forests of the Northern Rockies. We initially asked whether we should intervene. We have answered that, somewhat obliquely, by saying that we are here and we have impacted these forests both in what we have done and what we have failed to do. We have also indicated that we must modify our presence, our interventions in some ways.

The management of insects and diseases is affected by changes in forest management philosophy. The Forest Service is in the midst of a fundamental shift from the concept of managing forests for a variety of outputs to the concept of sustaining ecosystems that will meet the reasonable demands placed on them. This shift requires a greater awareness of the role of insects and diseases in maintaining natural ecosystems.

The Northern Region has made a major commitment to ecological sustainability in the Northern Rockies. The Northern Region has also recently completed a five-year plan of work that will tie the efforts of entomologists, pathologists, and others more closely to the overall ecosystem management approach. Three areas are critical for this effort: monitoring, planning, and resource management activities.

Monitoring: The annual surveys of pest conditions in the Northern Region have focused primarily on large-scale insect outbreaks. An emphasis on forest health requires that we monitor a broader spectrum of ecological indices. We must monitor not only defoliation and mortality caused by insects and diseases but also the effects of disturbance on forest vegetative succession. We must evaluate not only acres that have been affected but also acres at various levels of susceptibility to insects and disease.

Survey information must be mapped in relation to land management objectives. It must be applicable at different spatial scales for planning that will range from the landscape to the individual stand level. It must be accessible and comprehensible so that the public can provide land managers with informed opinions on management alternatives. The information must be compared to our planning assumptions so that management can be adjusted, if necessary.

Planning: Each of the National Forests in this Region has a Forest Plan that allocates lands to certain management classes, provides standards and objectives for the management of system lands. Forest Plans define a desired future condition for the land and project various amenities, services, and commodities from these lands. Forest Plans are subject to periodic revision as our understanding of the capabilities and ecological functioning of these lands improves.

In the past forest pest management specialists have contributed qualitative descriptions of the effects of insects and diseases as background for the planning process. In the future improved quantitative estimates of insect and disease impacts will be needed for both traditional and non-traditional management activities. A more complete portrayal of insect and disease impacts will be required in the forest prognosis modeling efforts. The extensive scale of insect and disease outbreaks, their potential for rapid development, and the intensity of their impacts must be considered at all levels of planning.

Management Prescriptions: Healthy forests require more than a reaction to the attack of insects and diseases on trees. In recent decades forest insect and disease management has been shifting from the direct control of pest populations to an integrated pest management (IPM) strategy that employs a variety of techniques.

As applied to forestry, our strategy must be more than a shift from chemical to biological pesticides. While direct suppression can be a part of an IPM strategy, the strategy also emphasizes the importance of understanding pest population dynamics, monitoring damage levels, and preventing conditions that favor population buildups. Silvicultural treatments that reduce insect and disease damage risks will play a major role in this strategy. Fire will be allowed a greater role in our landscapes.

Aesthetics, economics, and other issues will continue to affect forest practices. We must ensure that forestry practices done in the name of aesthetics, economics, or other public concerns are planned with a full awareness of the implications for forest health and ecological processes. Pest management specialists must describe in clear detail the effects of management alternatives—including the no-action alternative—on insect and disease dynamics and forest health.

We expect that our appreciation of insects and diseases will always have elements of conflict. Insects and disease outbreaks may indicate and contribute to ecosystem imbalance, a system that will not meet our management objectives. Insects and diseases can also play functional roles in maintaining healthy forests.

Distinctions between the functional and dysfunctional impacts of insects and diseases will not come easily. When IPM techniques are applied in agricultural settings, economic thresholds are established as criteria for intervention against insects and diseases. In forest environments the distinction between insects and diseases in functionally adaptive roles and insects and diseases as indicators of dysfunctional systems must be based on ecological thresholds. Ecological thresholds will be much harder to define than relatively simple cost-benefit thresholds. These ecological thresholds require that we understand the patterns and proper boundaries of change in natural ecosystems.

These new management efforts will require greater interdisciplinary cooperation among entomologists, plant pathologists, silviculturists, wildlife biologists, ecologists and other forest management specialists. An ecologically systematic approach is more than an integration of techniques. It is, most importantly, an integration of skilled people with a variety of perspectives and a shared commitment to healthy forests.

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