HEALTH DECLINES IN WESTERN INTERIOR FORESTS: SYMPTOMS AND SOLUTIONS

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ABSTRACT

When dealing with forest health issues, factors underlying the development of forests must be considered across time and space. Some subalpine forests of the Interior West are in good condition; however, most low-elevation forests have experienced significant changes in the last 100 years. Timber harvest, site preparation, grazing, fire prevention and suppression, and exotic pest introductions have changed these forests. They are denser; late seral species are more dominant; soil conditions may be altered; and they have more fuel and more fuel conductivity than ever before. Some of these factors have contributed to substantive changes in successional potentials, with accompanying differences in habitat characteristics. Such forests and associated components are now operating well outside their recent (1800-1900) historical range of variability. Often vegetal conditions (vertical and horizontal structure and composition), disturbance processes (fire, insect, disease), native species distributions, and habitat conditions supporting native species have been significantly altered. Current conditions suggest that without some rehabilitation, even greater changes are probable. Some changes may substantially reduce the inherent stability and productivity of these forest ecosystems.

Insects and pathogens, both native and introduced, have increased their activities substantially. Though insects are often viewed as the sole cause of declining forest health, forest decline is often a result of other conditions. Continued fire exclusion, without management to achieve forest mosaics similar to those resulting from historical disturbance regimes, will likely result in continued elevation of pathogen and insect activities, particularly in dry forests, and other forests nearby. In some cases, damaging populations of insects or pathogens (or their hosts) should be managed directly, but such actions are typically short-term solutions that buy time or allow prior investments to be capitalized. By dealing with larger scales, regional landscape mosaics and ecosystems can be managed. In these cases, insect and pathogen disturbance processes are indirectly realigned and solutions are more likely to be long-term. Aggressive management of introduced pests, like the white pine blister rust, can also be of major value in restoring normal forest conditions.

Keywords: pest management; pathogens; insects; historical range of variability

INTRODUCTION

Forests of the Interior West have undergone significant changes in structure, composition, and function during the last century. People have, directly or indirectly, initiated nearly all these changes. Many were inadvertent; others began with attempts to exploit ecosystems or to protect them from exploitation or "damage." Both professionals and citizens have noted in the last decade or two that the health of interior forests has been declining, likely as a result of recent human influences.

The concept of forest health has been poorly defined. For this discussion, a short definition of healthy forested ecosystems is:

> *Healthy ecosystems are those that retain the capacity to maintain structure and organization over time.*

Unhealthy ecosystems have lost this capacity in some manner. Usually the loss is brought about by a change in disturbance history, biotic processes, or environmental constraints. In this context, a significant change in genetic, species, or landscape diversity, soil or water productivity, air quality, or fire, insect, or disease disturbance regimes, is indicative of unhealthy ecosystems. By definition, unhealthy ecosystems are likely to be limited in their capacity to maintain sustainable resource values.

Acquiring knowledge of the developmental history of western, interior forest vegetation and environments is key to understanding forest disturbance processes. Disturbance histories are similar for much of the Idaho Panhandle, northeastern Oregon, eastern Washington, and western Montana. Also, the Interior West is rugged and mountainous, with diverse often recent geologic origins and variable temperate climates. Summer growing seasons are usually moisture limited; most moisture arrives as winter snow, and many soils are low in fertility.

Major disturbances were common in recent geologic time. Ash depositions from Cascade and Sierra volcanoes, (e.g., Mt. Mazama, 6,700 BP, Fryxell 1965), and the close proximity of continental glacial ice near Spokane, Washington, only 14,000 years ago are representative. Ash depositions increase soil moisture storage in some areas of the region, especially in more productive forests of northern Idaho, enabling vegetation characteristic of a wetter climate to prevail (Geist and Cochran 1991; Meurisse et al. 1991). Glacial scouring of many valley bottoms created thin, compacted soils. Glacial melt leading to the interglacial period reveals a generally warming climate over the last 10,000-12,000 years. Climate change and ash depositions have yielded constantly changing interior forests (Whitlock 1992).

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Temperature and moisture characteristics of forests in the region (wet, cold winters with warm, dry summers) limit biological decomposition (Olsen 1963, 1981). Accumulation of plant debris, combined with frequent lightning from summer thunderstorms that yield little precipitation, increases the probability of wildfire ignition (Habeck and Mutch 1973; Arno 1980). In the absence of fire, critical nutrients are sequestered in plant debris, and sites can become nutrient limited (Harvey, in press). These forests depend on microbes, arthropods, and fire to regulate carbon accumulation, nutrient availability, and nutrient cycling (Harvey et al. 1979; Harvey et al. 1994). Plant community instability is widespread in interior forests where many environmental variables are often simultaneously constraining. Individual species distributions are in a state of constant change, reflecting their sensitivity to numerous environmental thresholds. Plant assemblages are typically short term; the interdependencies of plants in such assemblages are often poorly developed (Whitlock 1992). Interior forests are dynamic and responsive to change; their evolutionary origins favored species and communities adapted to changing environmental conditions.

FOREST HEALTH CONCEPTS

Applying the concept of "health" in an ecosystem context to interior forests suggests consideration of temporal and spatial variability and similarities (or differences) between biophysical environments and their potentials. In this paper, we describe healthy interior ecosystems as:

(1) Biophysical environments with predictable site potentials, plant assemblages, and climate and disturbance regimes;

(2) Having structure and composition patterned by disturbances and environmental conditions;

(3) Moderately productive and diverse, with productivity and diversity varying predictably according to the pattern of successional (structural) stages and disturbance regimes;

(4) Resilient within normal climatic and disturbance regimes.

Forest Declines

Interest in forest health issues has been heightened worldwide. Recognition of potential problems with pollution, soil acidification, drought, pest epidemics, and potential climate change are driving this interest (Innes 1993). Such problems are often referred to as forest declines. Often the causes are complex and poorly understood (Schutt and Cowling 1985; see also Manion and Lachance 1992). In some cases, concerns have been alleviated because the changes were associated with natural stand or landscape dynamics (Lohle 1988). Predictions in the early 1980's, that the forests of central Europe would shortly expire as a result of "acid rain" have not materialized. However, these forests and forests in many parts of the world are experiencing extensive ongoing health problems (Innes 1993).

Natural Roles of Native Insects and Pathogens

Because historical environments were diverse and constantly changing, vegetation was under frequent stress. Biological decomposition was constrained under moisture-limited environmental conditions, but recycling of nutrients was assured by fire (Olsen 1981). Fire-adapted species dominated frequently burned sites. Most native forest pathogens and insects are vigor sensitive; they tend to successfully attack, colonize, and overcome low vigor or stressed trees (Waring 1987; Stoszek 1988). The greatest amount of tree mortality typically occurs in vegetation that is under stress or poorly adapted to local site conditions; such mortality is an obvious benefit to forest ecosystems and to genetic diversity (Harvey et al. 1992). Some pathogens and insects shorten nutrient cycles, others accelerate decomposition; in either case the benefits to the ecosystem can be substantial (Martin 1988; Haak and Byler 1993; Harvey, in press). Localized centers of insect and disease activity create diversity in forest structure and composition, which are also beneficial (van der Kamp 1991; Hessburg et al. 1994).

The pathogens and insects of interior forests have stabilized and diversified forest communities occupying resource-limited sites in an ever-changing climate. Insect and disease disturbances are integral to the ongoing evolution of forest structure and composition (Martin 1988; Burdon 1991; Jarosz et al. 1991; Harvey et al. 1992, in press; Hessburg et al. 1994).

Introduced Organisms

Within the ranges of western white (*Pinus monticola* Dougl.), whitebark (*Pinus albicaulis* Engelm.), limber (*Pinus flexilis* James), and sugar pines (*Pinus lambertiana* Dougl.), introduction of the white pine blister rust fungus (*Cronartium ribicola* J.C. Fisch.) early in this century disrupted forest ecosystem structure and composition. In the last 40 years, the distribution and dominance of five-needle pines (especially western white pine) has been reduced by more than 50% (Monnig and Byler 1992; O'Laughlin 1993).

Other exotic pathogen and insect introductions have caused similar devastation worldwide (Burdon 1991). Such introductions typically cause significant shifts in ecosystem structure and organization because native host populations lack evolved tolerance to exotic pests (Jarosz et al. 1991). Change in system organization may take extended periods of time, depending on the degree of disruption and its effects on other processes. While the ecosystem is changing, its system productivity and stability are likely to be reduced.

CURRENT CONDITIONS IN WESTERN INTERIOR FORESTS

Declining forest health is widely publicized in dry forests throughout eastern Oregon and Washington, especially in the Blue Mountains of Oregon (Gast et al. 1991; Wickman 1992) and, more recently, in the Boise and Payette National Forests of Idaho (O'Laughlin 1993). Less well known is the decline in

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health of the moister, more productive forests typical of northeastern Washington, northern Idaho, and western Montana (Monnig and Byler 1992). Variation in the species composition of Idaho's forests over the last 35 years indicates fundamental changes in ecosystem structure and organization. These changes cannot be explained by historical patterns (Figure 1).

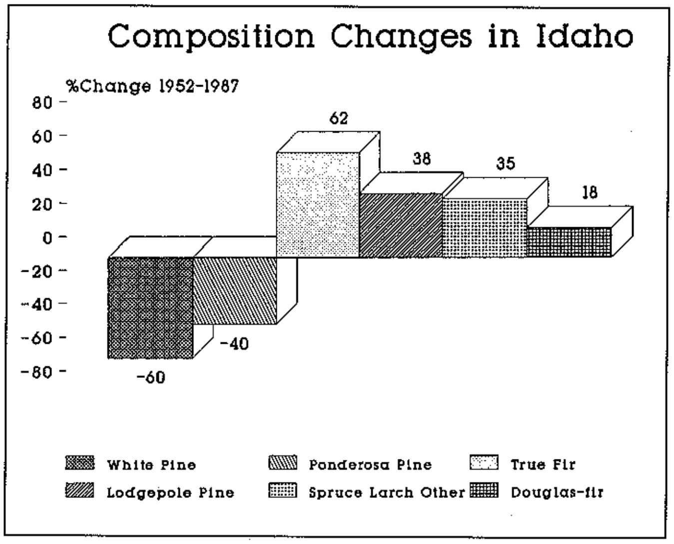

Figure 1.—Species composition changes over 35 years in Idaho forests. Note extreme change in pines vs. fir. White pine losses are typical of northern Idaho; ponderosa pine losses are typical of the dry forests in the southern Panhandle (O'Laughlin 1993).

Warm, Dry Forests

Two striking changes have occurred to dry forests in recent times. Formerly, recurrent low-intensity fires regulated competition for limited site resources (e.g., water and nutrients) by eliminating fire-intolerant trees. With the effective exclusion of underburning fires in this century, dry forests quickly became overstocked, exceeding their productive potential. In the absence of fire, native insects and pathogens regulate stocking by killing susceptible individuals and species. Formerly, frequent underburning fires prevented excess accumulation of carbon (C) in woody biomass by consuming and releasing nutrients. With fire excluded, organic residues have accumulated, as have the volumes of standing live and dead wood.

Figure 2 is a schematic, showing differences between historical and modern C accumulation processes, the cyclic nature of historical C accumulation, and the balance between fire and biological decomposition in regulating C accumulations in historical forests of the region. Biological decomposition is severely limited (Harvey et al. 1979; Edmonds 1991). The current danger to these forests is not just stand-replacing wildfire, but wildfire with fuel accumulations so high that resulting burns are extremely hot, critically reducing stored nutrients through volatilization, with accompanying losses to potential productivity (Harvey et al. 1994).

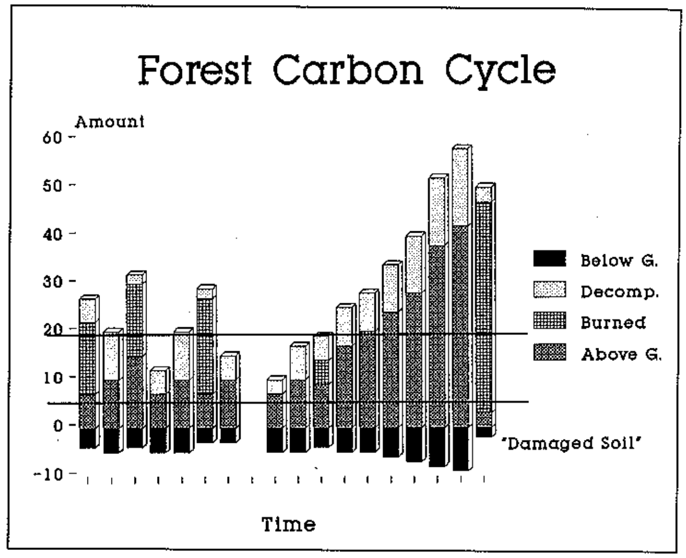

Figure 2.—Carbon cycle schematic. Left is normal, short-cycle, right is imposed fire control or long-cycle. Negative is below-ground C. Between lines is common condition. Entire bar shows historical range (Harvey, in press; Oliver et al. 1994).

The effectiveness of fire prevention and suppression in dry interior forests in recent years has permitted greatly increased ground fuel accumulations and stratified fuels (both living and dead); many fires can no longer be contained or confined. They now burn hotter and more extensively than they did just 20 years ago (Brown 1985; Baker 1992; Auclair and Bedford, in press). This effect has been greater in warm, dry forests that historically experienced more frequent (every 15 -25 years) fires than warm-moist, transitional, or cool forests that burned much less frequently (Figure 3).

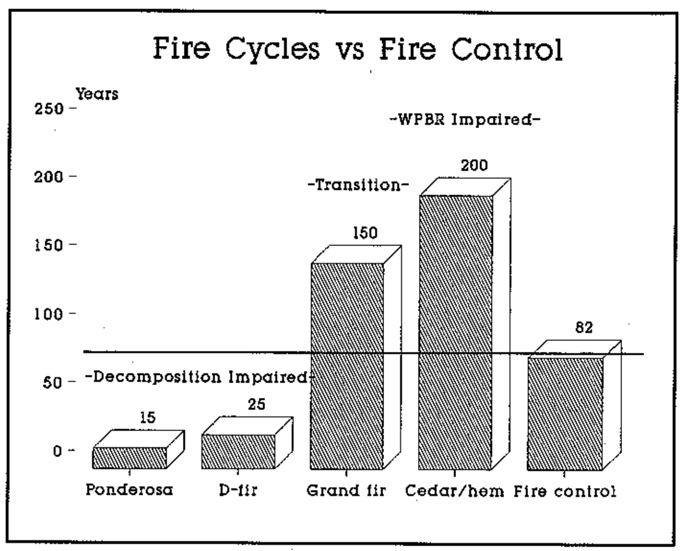

Figure 3.—Comparison of length of period for effective fire control (since 1911) to length of normal fire cycle (Heinselman 1978). White pine blister rust is abbreviated WPBR.

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Boise Basin forests are typical of those historically governed by low-severity, frequent fire regimes; they supported low densities dominated by ponderosa pine (*Pinus ponderosa* Laws.). Starting in 1911, fire prevention and control began to extend the fire cycle, rapidly increasing tree density, and shifting dominance from ponderosa pine to shade-tolerant, pest-susceptible Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco). Accompanying these changes was an increasing rate of tree mortality. On the Boise and Payette National Forests, tree mortality associated with insects and diseases currently exceeds tree growth (O'Laughlin 1993). In eastern Oregon and Washington, tree mortality has also increased significantly in recent decades (Gast et al. 1991; Hessburg et al. 1993), although tree growth still exceeds mortality.

The forests just discussed can be considered unhealthy, not only because of their widespread insect outbreaks and disease epidemics, but also because of their highly altered fire disturbance and nutrient cycling regimes. In the absence of frequent underburning, native pathogens and insects of warm, dry forests play a larger role in forest disturbance: reducing excessive intertree competition for limited site resources, increasing nutrient storage in woody biomass, and ultimately increasing the susceptibility of forests to lethal fires and losses in productivity. Most of the current decline in forest health can be traced to a near-epidemic increase in trees on sites where frequent underburning prevented such increases in the past (Weaver 1943; Gast et al. 1991; Hessburg et al. 1994, Figure 4; Harvey, in press).

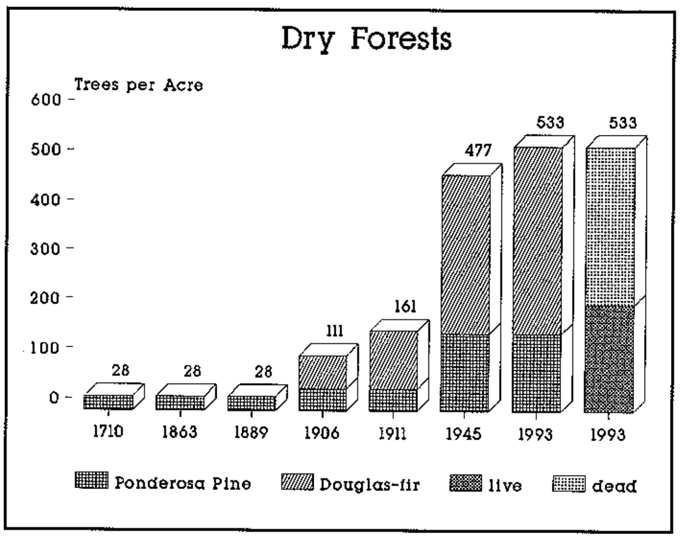

Figure 4.—Historical conditions and recent increases in density and changes in species composition typical of dry forest regions once dominated by ponderosa pine (Sloan 1994).

While some dry forests remain in a relatively natural condition, most are plagued by the effects of fire exclusion. In many dry forests, the selective harvest of seral species has compounded the effects of fire exclusion by favoring release and accelerated regeneration of shade-tolerant species (Gast et al. 1991; Hessburg et al. 1994; Oliver et al., in press). Without some form of intervention or rehabilitation, conditions can be expected to worsen (Sampson et al., in press).

Warm, Moist Forests

In contrast with warm, dry forests, biological decomposition in warm, moist forests is substantial (Harvey 1994; Edmonds 1991), and the role of fire in nutrient cycling is reduced (see also Figures 2 and 3). A significant factor in the decline in health of these forests is the reduction of western white pine abundance by the blister rust fungus (Figure 5). Such widespread mortality has diminished the roles white pine once played as a major seral species, and has expanded the roles of late-successional species and their associated pathogens and insects. Tree density and volume do not necessarily increase with changes in species composition in warm, moist forests because of their inherently greater productivity and carrying capacity.

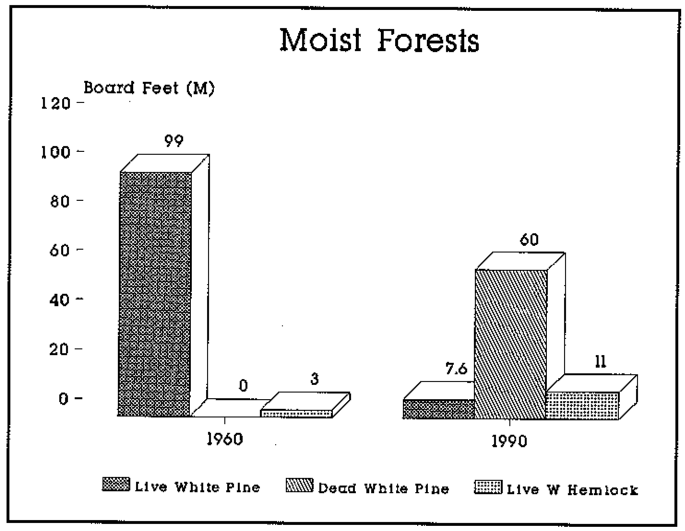

Figure 5.—Comparison of conditions in northern Idaho white pine forests once dominated by western white pine (as recently as 1960), now dominated by western hemlock. Note volume is reduced rather than increased as for dry forests (Moeur 1992).

Forests typified by ordinarily low rust hazard, and those with historically low white pine stocking levels remain in relatively good health. Exceptions are those with increased root disease incidence associated with the increased dominance of shade-tolerant species (Baker 1988; McDonald 1991; McDonald et al. 1991; Monnig and Byler 1992).

In high rust hazard forests, western white pine no longer dominates in the overstory as in the past. These forests are now dominated by Douglas-fir, grand fir (*Abies grandis* [Dougl.] Lindl.), white fir (*Abies concolor* [Gord. & Glend.] Lindl.), and western hemlock (*Tsuga heterophylla* [Raf.] Sarg.); root diseases play a much greater role because these species are more susceptible (Monnig and Byler 1992). The effects of blister rust are no longer highly visible because the white pines have already been lost.

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Although great increases in volume and stocking of living trees are not as evident as in dry forests, a serious ground fuel buildup can develop. Fuel accumulation associated with previous white pine blister rust mortality can be substantial, and an increasing accumulation of dead Douglas-fir and true fir (*Abies* spp.) fuels is expected with expanding root disease mortality. Additionally, conversion of tall, well-spaced white pine forests to low, densely stratified Douglas-fir and true fir forests results in hazardous fuel ladders. Significant changes in potential fire behavior are characteristic of modern-day, moist interior forests. Such changes threaten future fire control efforts and place neighboring forest ecosystems and values at risk.

Transition Forests

Transition forests (warm, dry to warm, moist) possess most of the features of both dry and moist forests. Landscapes were historically a complex patchwork of stands resulting from fires that produced both lethal and nonlethal effects. Due primarily to the influences of fire exclusion and selective harvest, modern-day transition forests are far more homogeneous than historical forests (Lehmkuhl et al. 1994). Loss of landscape diversity is primarily associated with increasing dominance and layering of shade-tolerant species in stands previously dominated by open-growing ponderosa pine or other seral species.

Greater fuel accumulations and significant changes in potential fire behavior are characteristic of stands with relatively short historical fire cycles. Mixed severity fires are now an improbable occurrence in many transition forests. As in moist forests, the greater the historical abundance of white pines, the greater is the effect of blister rust on resulting species composition and disturbance processes. Since the rate of biological decomposition is more highly variable in transition forests, depending on temperature and moisture regimes, variations in stand histories result in extreme variations in fuel accumulations. Similarly, short-term climate episodes such as drought produce highly variable and often pronounced effects on tree stress depending on current tree densities and recent historical moisture regimes.

Cool Forests

The white pine blister rust also causes extensive mortality in high elevation, cool forests throughout the Interior West (Hoff and Hagle 1990; Keane and Arno 1993; Keane and Morgan 1994). With recent reports of the rust in white pine of the desert Southwest, it appears that similar ecological effects will occur in those ecosystems before long (Hawksworth 1990; Shaw et al. 1993). Blister rust mortality is increasing in high-elevation whitebark and limber pine ecosystems throughout much of the Northern Rocky Mountains; conversion of these to ecosystems dominated by subalpine fir and Engelmann spruce is anticipated. Insects and diseases of subalpine fir and spruce can be expected to play expanded roles in these forests. Fuels will accumulate with increasing pathogen and insect mortality, and fire regimes will likely be modified. The eventual effects of blister rust on fire, insect, and disease disturbance regimes, and on community structure and organization remain to be seen. As in other ecosystems dominated by five-needle pines, introduction of an exotic species is the primary agent of change, and subsequent changes in disturbance regimes will follow.

CONCLUSIONS AND RECOMMENDATIONS

Insects and pathogens, both native and introduced, have increased their activities substantially in western interior forests. Although insects and pathogens are often viewed as the sole cause of declining forest health, this decline is more often a result of other forest conditions. Continued fire exclusion, without management to achieve forest mosaics similar to those resulting from historical disturbance regimes, will likely result in continued elevation of pathogen and insect activities, particularly in dry and transitional forests, and in others nearby.

In some cases, damaging populations of insects and pathogens (or their hosts) should be managed directly, but such actions are typically short-term solutions. In most cases, regional landscape mosaics and ecosystems should be managed. By managing at larger scales, insect and pathogen disturbance processes are indirectly realigned; these solutions are more likely to be long term. Introduced pests, like the white pine blister rust, can be managed by screening host trees for rust resistance and deploying improved stock to aid restoration (Hagle et al. 1989).

Innovative management will be needed to realign disturbance processes, vegetation structure, and composition with existing biophysical potentials. No single remedy will work; diverse tools will be needed. In some cases, return to historical norms will be desirable and feasible. In other cases, a return to historical norms may be socially or ecologically infeasible. In general, multiple treatments will be needed to regulate vegetation structure, composition, and associated biomass loadings. Long management horizons may be required to restore unhealthy ecosystems to more sustainable conditions.

Management strategies for restoring health and sustainability to dry and transition forests seem relatively clear. Management strategies should incorporate knowledge of historical and current disturbance regimes, site potentials, and climates. Successional trajectories that will yield sustainable forest conditions can be deduced by considering directions, rates, and magnitudes of change between historical and current conditions. Where this information is lacking, it can be obtained. Where data are available, they should be refined.

Current conditions and future prognoses for these forests suggest that the most effective means to restore long-term forest health will be density and fuels management, plus regulation of species composition to improve the dominance and distribution of seral species (Oliver et al. 1994a). Management of transitional forests will require particularly careful analysis of site conditions so more complex landscapes can develop, not only because of their vegetal structure and composition, but because of the effects they will have on disturbance processes.

Management strategies for moist and cool forests are less obvious, but should follow similar ecological cues. Roles of major forest pathogens and insects, other microbes, and arthropods are currently recognized as important, but are as yet poorly

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understood (Harvey et al. 1992, in press; Haak and Byler 1993; Harvey, in press; Hessburg et al. 1994). Greater insight is needed in this relatively new area of ecological research. Ordinating interior forest ecosystems by habitat type or plant association groupings that reflect productivity; fire, insect, and pathogen behavior; and microbial and arthropod ecology has been proposed by McDonald et al. (1991) and Hessburg et al. (1994). Since processes are tightly linked, such an approach appears to have considerable potential, both for site-specific and more general ecosystem analyses. To do so would require a substantial investment in ecological inventory and classification.

Analyses such as these will be critical to guiding interior ecosystems toward more predictable and sustainable future conditions. An outline for one proposed system is presented in an accompanying paper (McDonald et al., this proceedings).

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