A FOREST HEALTH PERSPECTIVE ON INTERIOR DOUGLAS-FIR MANAGEMENT

James W. Byler and Sara Zimmer-Gorve

ABSTRACT

We review concepts of integrated pest management and forest health and discuss a strategy for achieving and maintaining productive and healthy forests. The strategy is illustrated using interior Douglas-fir as the example. Interior Douglas-fir is seriously damaged by Armillaria and Phellinus root diseases, western spruce budworm, Douglas-fir dwarf mistletoe, and other insects and diseases. The severity of these problems can be traced to man-caused disturbance of white pine blister rust, and forest management practices. The long-term solutions to these problems in natural forests require biologically sound forest management practices.

Keywords: Integrated pest management, root disease, dwarf mistletoe, western spruce budworm, white pine blister rust

INTRODUCTION

The National Office of the Forest Service recently completed an assessment of the health of the Nation's forests, and published a strategic plan to enhance and maintain that health (USDA Forest Service 1988). In so doing, they have focused a national effort on key issues of forest health.

Douglas-fir is a major tree species throughout the Interior West, and has increased in abundance during the present century as a result of a number of management activities, including fire control. The species is also affected by a number of damaging forest insects and pathogens.

We believe it is useful to view Douglas-fir management from the perspective of forest health, and will offer some ideas for thought. Specifically, our objectives are:

1. To present a concept of forest health using an analogy with human health.
2. Develop an ecological basis for a forest health strategy.
3. Illustrate use of the forest health strategy in the management of interior Douglas-fir forests.

THE FOREST HEALTH CONCEPT

A healthy forest has been defined as 'a condition where biotic and abiotic influences on the forest do not threaten management objectives for a given forest unit, now, or in the future.' (USDA Forest Service 1988).

Thus, a healthy forest may not be insect-free or pathogen-free, but sufficiently free of pest damage to meet management objectives. Furthermore, it can be maintained in such a condition that it will meet the objectives of future generations—objectives that may be different from ours. The concept might be expressed in terms of function. By this definition, a healthy forest might be viewed as a fully functional community of plants, animals, and their environment. In ecological terms, a healthy forest might be a balanced ecosystem.

An analogy with human health might be useful. Human health has historically emphasized treatment of illness as suggested by the terms 'medical profession' or 'medicine.' Recently, the emphasis has been shifting to 'wellness.' Our lifestyle may contribute more to our health than does genetics, environment, and health care, as important as these are. Regular exercise, proper diet, and other personal habits have a greater effect on our well-being than does treatment of illness. Further, knowing what behavior puts us at risk allows us to modify that behavior and reduce our risk.

Integrated pest management has been the dominant forest pest management strategy for the past 20 years (Stark 1970; Franz 1971). Integrated pest management has been official USDA Forest Service policy for more than a decade (USDA Forest Service 1979). This strategy grew out of a reevaluation of an earlier emphasis upon direct suppression.

Integrated pest management includes a broad range of prevention and suppression activities, the application of which is based on sound economic, sociological, and ecological factors (Franz 1971; Stark 1970). The need to make integrated pest management a component of resource management was recognized early, as was the need to understand insect outbreaks in ecological rather than entomological terms (Stark 1979). In practice, however, integrated pest management has continued to focus, to a large degree, on the 'pest,' not the ecosystem, and pest suppression, not silvicultural tactics (USDA Forest Service 1988).

Forest health puts the emphasis on prevention. Insect and disease management then becomes one of recognizing stand conditions and site factors that put stands at risk of damage, and of modifying stand conditions through the appropriate use of silvicultural procedures, including the use of prescribed fire.

THE ECOLOGICAL BASIS FOR A FOREST HEALTH STRATEGY

The justification for forest health, like integrated pest management, is based in forest ecology theory. J. G. Leach, who taught principles of plant pathology at West Virginia University during the early 1960s, (pers. comm.) used the phrase *'biological balance'* to describe the equilibrium that develops between pathogens, their hosts, and the environment in natural ecosystems. The concept has also been called 'ecological balance' or 'balance of nature' (Balch 1965). The balance is dynamic and fluctuates through time as ecosystems undergo cycles of

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.

successional change. But there are limits to the change that can occur in natural ecosystems, limits set by checks and balances developed through generations of co-evaluation. Actions that upset the ecological balance may bring unpredictable and undesirable changes, changes that may be irreversible (Leopold 1933). The classic examples of disturbance to the biological balance are introductions of exotic plants and animals, but the balance may be altered in many other ways.

Pest management strategies for agricultural crops have relied heavily on pest prevention and suppression technology, including the use of fungicides and insecticides. Baker (1965) suggested that the development of disease control technology has just about offset the favorable conditions we created for pathogens by plant breeding, monoculture, and in other ways simplifying natural ecosystems.

Differences between agricultural pest management and forest pest management have been recognized (Stark 1970; Franz 1971). The differences include not only the greater biological diversity and ecosystem stability in forests, but also a greater ability to sustain damage, a wider range of values, and longer 'crop' life.

In actuality, a wide spectrum of management intensity (and loss of ecosystem diversity) can be found in forestry practice. The focus upon integrated pest management techniques under all conditions has tended to obscure those differences as they relate to pest management. More attention needs to be given to matching pest management strategies to the particular situation and values at stake. The full range of integrated pest management techniques may be needed, and justified, in nurseries where values are high, cultural systems are simplified, and opportunities to modify crop management procedures are great. At the other end of the spectrum, the management of native pathogens and insects in natural forests can be accomplished through 'routine silvicultural practice.' (Boyce 1961).

Why, then do we have major outbreaks of insects and diseases on interior Douglas-fir within the range of this species in the Intermountain West? Stark (1970) mentioned the accumulating evidence that outbreaks of forest insects are symptomatic of ecological disturbances in forest ecosystems. The literature from the Intermountain Region also suggests the same. Man's activities of the present century have greatly altered the character of western forests, changed some of them in ways that have upset the biological balance that existed in the natural forests, and by so doing brought about serious pest outbreaks.

In most cases, the damage is reversible in managed forests through silvicultural techniques. The knowledge upon which to base sound treatments comes from the study of insect and disease ecology as it relates to the ecology of natural and disturbed forests. It is not enough to grow native tree species with the usual regeneration and stocking control measures, and assume our pest problems can be suppressed if and when they occur. To succeed, silvicultural systems must consider the role of these agents in natural ecosystems, how they respond to management practices, and what factors put stands at risk of damage. Insects and pathogens seem to be responsive to relatively small changes in forest ecosystems. The 'biological balance' appears relatively fragile as illustrated by some interior Douglas-fir forests.

IMPLEMENTING FOREST HEALTH THROUGH SILVICULTURAL TREATMENTS OF INTERIOR DOUGLAS-FIR STANDS

Interior Douglas-fir is seriously damaged by a number of insects and diseases including western spruce budworm, Armillaria and Phellinus root diseases, fir-engraver and Douglas-fir beetles, and Douglas-fir dwarf mistletoes. Alone, and in combination, these insects and diseases affect millions of acres annually in the Intermountain West. We will give a brief review of these major insects and diseases, focusing on conditions that put stands at risk and opportunities to improve forest health through silviculture.

Our goal is *not* to develop stand prescriptions. That is a site-specific job for silviculturists. We also do not plan to present technical details—those will be given from subsequent speakers and are available in the literature.

We will use as our example two forest types of the Northern Region. The first will be forests of western Montana, on Douglas-fir habitat type series, in which ponderosa pine was the predominant species before arrival of the European influence. Our second example will be in forests of northern Idaho, on hemlock, cedar and grand fir habitat types, in which western white pine was the major species.

It is clear that forests of the northern Rocky Mountains have been greatly changed during the present century (Gruell 1983). We believe some of our most damaging insect and disease problems are the result of these changes which upset the biological balance that existed in the natural forests. We will review some ways that ponderosa pine and western white pine forests were changed, show how some of these changes have put the present forest stands at risk from certain insects and pathogens, and review silvicultural techniques that can be used to improve forest health and productivity.

Western Montana Ponderosa Pine Forests

The vegetation has been greatly changed over the past 70 years, in what were once ponderosa pine forests in western Montana (Arno 1988; Arno *et al.* 1985; Fisher and Bradley 1987; Gruell *et al.* 1982). Frequent surface fires historically played a major role in stand development, particularly in habitat types with the Douglas-fir series (Pfister *et al.* 1977), through selectively killing the fire-susceptible Douglas-fir and maintaining open stands of predominantly ponderosa pine. Fire control and selective harvesting of higher value pines has changed the course of forest succession on these sites. Open ponderosa pine stands have been converted to dense stands, composed largely of Douglas-fir.

These management practices have put many stands at risk from western spruce budworm (*Choristoneura occidentalis*) and contributed to the increased duration and intensity of outbreaks by creating more favorable budworm habitat. Budworm feeds primarily on the foliage of Douglas-fir and true fir trees. Damage is most severe on trees growing in stressed conditions.

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.

Thus, the conversion of these stands to Douglas-fir increases the availability of food for the budworm. In addition, because Douglas-fir is better able to regenerate itself under the canopy than ponderosa pine, a multi-storied stand develops of host beneath host. With increasing canopy closure, the stresses of the site increase. This adds to the availability of appropriate food. The multiple canopy layers also provide refuge from predation, parasitism, and adverse weather conditions.

Suppression and prevention are the management strategies used to treat budworm outbreaks. Suppression using chemical or biological insecticides can reduce damage the year following treatment, but has not changed the course of an outbreak (Carlson *et al.* 1983). Prevention involves recognition of conditions which will create favorable budworm habitat and changing these conditions (Carlson *et al.* 1983; Carlson and Wulf 1989). The silvicultural techniques used to reduce budworm habitat will depend on the management objectives for the stand. Two sites where budworm will be a prominent problem of Douglas-fir are the sites where it is the only tree species (east of the Continental Divide) and where Douglas-fir and ponderosa pine grow together. On the pure Douglas-fir sites, the species should be grown at densities and spacings that compliment site productivity. The stands should be fairly open to prevent the interception of budworms by the understory crowns. On the ponderosa pine/Douglas-fir sites, pine should be favored for timber management. Each regeneration cut should include the harvest of each species with site preparation to promote the regeneration of ponderosa pine. The harvest method should favor ponderosa pine and reduce competition from Douglas-fir. Avoid using Douglas-fir as the sole basis for the next stand.

Recognizing stand conditions that promote budworm habitat and changing those conditions will do much to reduce budworm outbreaks. Maintaining stand density to within site class limitations, promoting growth of seral trees, and reducing the occurrence of suppressed host understory beneath a host-dominated overstory will reduce the potential for budworm outbreaks and intensive damage.

Armillaria root disease has also become a serious concern in many Douglas-fir stands throughout the Interior West (Hadfield 1984; Wargo and Shaw 1985). Evidence indicates that the incidence of this root disease may be correlated with sites in the Douglas-fir habitat type series on which surface fires have maintained predominantly seral species (Byler *et al.* 1990). Less is known about Armillaria risk factors than about those favoring western spruce budworm or dwarf mistletoe. Nevertheless, it is clear that the disease is favored by activities that create stumps to serve as food bases for the fungi and increase the abundance of Douglas-fir, which is the most susceptible host species on disease-prone sites (Byler 1984; Hadfield 1984; Hagle and Goheen 1988).

The basic approach to managing Armillaria root disease is also silvicultural, i.e., by regenerating disease-prone sites to mixed stands of disease-tolerant species that are site-suited and have historically occurred there (Hadfield *et al.* 1986; Hagle and Goheen 1988; Morrison 1981). For the Douglas-fir habitat type series, the appropriate species are typically ponderosa pine and western larch. The removal of infested stumps offers some promise (Roth *et al.* 1977), and may be useful for special situations, but is not widely practiced. Losses in severely affected merchantable Douglas-fir stands can be reduced by early harvest (pathological rotation). But the only economical, long-lasting solution to Armillaria root disease in interior mixed conifer stands is by regeneration to disease-tolerant species.

Douglas-fir dwarf mistletoe has also responded to management practices that occurred earlier in this century—practices that facilitated dwarf mistletoe spread and intensification (Alexander and Hawksworth 1975). Historically, wildfires tended to reduce both acreage affected and degree of infestation. Fire control and various forms of partial cutting have created susceptible regeneration beneath infested overstories. The aging of infested stands has increased buildup, as well.

Silvicultural control methods for dwarf mistletoes have been known since early in this century (Gill and Hawksworth 1961). The major opportunity to increase stand health and productivity is to eliminate or reduce dwarf mistletoe on infested acres at the time of regeneration. This can be done by removing the infected species or regenerating to non-host species. In managed forests, other means of dwarf mistletoe are rarely needed.

Northern Idaho Western White Pine Forests

The historic role of fire appears more complex on habitat types in which the grand fir, cedar, and hemlock are climax than in the Douglas-fir series discussed above (Arno and Davis 1980; Marshall 1928), and that role not as well documented. Nevertheless, it is clear that the forests of today are much different than those that formerly occupied these sites. Pure and predominantly white pine stands covered millions of acres in northern Idaho in the 1880s (Haig *et al.* 1941). A generalized forest successional model can be constructed based on the literature (Haig *et al.* 1941; USDA Forest Service 1913; Watt 1960):

1. The establishment of a mixed species stand following a stand replacement fire;
2. The early elimination of Douglas-fir to root disease, and larch, lodgepole pine, and other species due to suppression; and
3. The continuation of a pure or nearly pure white pine forest from about age 150-250 years, when increasing mountain pine beetle mortality again set the stage for a stand replacement fire.

Today, western white pine is nearly always a minor stand component. Douglas-fir, which formerly was 'usually present, but seldom abundant,' (Watt 1960) and grand fir, also susceptible to root disease, predominate in most stands. The most important cause of the change appears to be the introduction of the white pine blister rust fungus into western forests. This fungus eliminated most white pines from young stands that regenerated following wildfires and regeneration harvesting. Selective harvesting of high-value species contributed to the process, favoring grand fir and Douglas-fir (Wellner 1984).

Root pathogens, particularly laminated root disease and Armillaria root disease, have benefited from these changes (Byler *et al.* 1990). Douglas-fir beetle and fir engraver beetles are also common causes of Douglas-fir and grand fir mortality,

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.

particularly on root diseased trees. The elimination of the overstory Douglas-fir and grand fir, and subsequent regeneration and death of these species on grand fir habitat types, results in what appears to be a self-perpetuating root disease center, with little timber volume accumulation. On the cedar and hemlock series, these species replace the Douglas-fir and grand fir that are killed by root disease comparatively early, often at less than 100 years of age. The western white pine stage of succession is omitted. The timber resource has been greatly reduced, and watershed values have been affected as well (Hagle, S. K., pers. comm.)

Thus, the inadvertent introduction of white pine blister rust had a major, devastating effect. It not only limited the growth of western white pine on these sites, but in so doing, upset the biological balance of this ecosystem, such that the replacement forest has been severely damaged by native root pathogens.

Recreating healthy and productive forests on the appropriate scale will be a large undertaking. Managers must deal with the present diseased stands as best they can, capturing volume that would otherwise be lost to root disease. They can increase the proportion of white pine that will survive to rotation age by pruning on lower rust-hazard sites. But the long-term solution to laminated root disease is the same as for Armillaria: to regenerate disease-prone sites with disease-tolerant species (Hagle and Goheen 1988; Hadfield 1985; Hadfield *et al.* 1986). Rust-resistant western white pine is a key component of that solution in northern Idaho, where the species historically occurred in abundance, often in pure stands. Extensive planting of rust-resistant stock will increase selection pressure on the rust and the likelihood of a breakdown of resistance. But this can be minimized, and the useful life of this material can be extended by the use of different types of stock with different levels of resistance, as suggested by Hagle *et al.* (1986).

CONCLUSION

We have tried to express the older concept of forest pest damage prevention in new terminology, that of forest health. We suggest that a forest health strategy need be based on an understanding of forest ecology *and* insect and pathogen ecology. The practice of achieving and maintaining healthy, natural forests is accomplished through silvicultural practice that is based on this understanding. Exceptions to this strategy are required for introduced insects or pathogens that disrupt natural ecosystems to such an extent that the process cannot be reversed through silviculture, and for high-value crops, such as nursery-produced seedlings. Tree breeding and biological control techniques have been successful for introduced pathogens and insects. Integrated pest management techniques are appropriate for nursery disease control.

We know that interior Douglas-fir is now the predominant species on many sites on which it historically was a minor one, and it often occurs in dense, multi-storied stands. We understand the causes of this from studies of forest ecology. We also realize that many of our most damaging insect and disease problems are those affecting interior Douglas-fir, and we believe the magnitude of these outbreaks can be traced to man-caused changes in forest conditions that tipped the biological balance to favor these agents. The long-term solutions to these problems are stand management practices that reestablish that balance in natural forest ecosystems. This will mean a lesser proportion of Douglas-fir on many sites.

Much progress has been made during the past two decades or so, with regard to integrating insect and disease management. Many in this audience contributed to this progress. Some valuable research has been done recently on factors that put stands at risk, particularly from western spruce budworm, and the effects of silvicultural treatments on insect and disease damage. A major contribution has been made by state and forest pest management entomologists and pathologists through formal and informal training of silviculturists and others who prepare and implement silvicultural prescriptions. Probably, most credit should go to certified silviculturists who have put the theory into practice. We have seen a steady improvement in the quality of insect and disease management at the Forest and District level over the past 20 years.

But major challenges remain and new ones face us. The progress we have made is with stands managed primarily for timber. Insect and disease activities continue in unmanaged stands and stands managed for other values. Some of the changes they cause, such as an increase in the risk of wildfire, affect non-timber values of those lands. Methods for managing such stands using prescribed fire and perhaps other means are needed. A new challenge is to develop biologically sound silvicultural alternatives to clearcutting, when possible, and to gain public acceptance for short-term visual impact to achieve long-term gains in other values.

Spurr and Barns (1980) point out that forest practice may take many different forms. One form is the agriculturist approach, the culture of desired crop species in artificially made communities. Another is the naturalistic approach that suggest nature's way is best and safest. But a wide middle-ground exists between the two extremes.

Increasingly, the agriculturist approach is being questioned for western forests, and a middle course has been suggested (Franklin 1989). From the forest pest management standpoint, it is clear that the agriculturist approach requires costly insect and disease management technology, at best. On the other hand, non-management can lead to undesirable insect- and disease-caused changes. The exclusion of fire, sometimes needed for human safety and other reasons, has increased insect disease outbreaks in Douglas-fir forests. The middle course Franklin suggests will also facilitate the management of the health of western forests.

We have the basic knowledge of insect and disease behavior needed to manage forests containing interior Douglas-fir, even though we lack much important information. We don't believe we have the knowledge to deviate very far from those processes. To ignore the responses of insect and diseases of Douglas-fir to major shifts in stand composition, stocking and structure, for example, can intensify already serious problems. The lessons of the past are that insects and pathogens respond to ecosystem changes, that not all of these responses can be foreseen, and that the effects of these experiments may not be apparent for several decades.

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.

LITERATURE CITED

Alexander, M. E. and F. G. Hawksworth. 1975. Wildland fires and dwarf mistletoes: a literature review of ecology and prescribed burning. USDA Forest Service, Rocky Mountain Station. GTR RM-14. 12 pp.

Allen, G. E. and J. E. Toth. 1980. The conceptual and institutional aspects of integrated pest management. Bioscience 30(10):658-664.

Arno, S. F. 1988. Fire ecology and its management implications in ponderosa pine forests. p. 133-139. *In:* Ponderosa Pine: The Species and Its Management, D. M. Baumgartner and J. E. Lotan, eds., symposium proceedings, September 29-October 1, 1987, Spokane, WA. Washington State Univ. Coop. Ext., Pullman.

Arno, S. F. and D. H. Davis. 1980. Fire history of western redcedar/hemlock forests in northern Idaho. p. 21-26. *In:* Proceedings of a fire history workshop, M. A. Stokes and J. H. Dietrich, Technical Coordinators, October 20-24, Tucson, AZ. USDA Forest Service GTR RM-81. 142 pp.

Arno, S. F., D. G. Simmerman and R. E. Keane. 1985. Forest succession on four habitat types in western Montana. USDA Forest Service GRT INT-177.

Baker, K. F. 1965. A plant pathogen view history. History of Botany. The Clark Memorial Library, Univ. Calif. Los Angeles. p. 36-70.

Balch, R. E. 1965. The ecological viewpoint. CBC Publications, Box 500, Toronto 1, Canada. 58 pp.

Byler, J. W. 1984. Status of disease pests of the interior Douglas-fir and grand fir types. p. 45-50. *In:* Silviculture management strategies for pests of the interior Douglas-fir and grand fir forest types. Baumgartner, D. M. and R. Mitchell, eds. Proceedings of a symposium February 14-16, 1984, Spokane, WA. Washington State Univ. Coop. Ext., Pullman.

Byler, J. W., M. A. Marsden and S. K. Hagle. 1990. The probability of root disease on the Lolo National Forst, Montana. Can. J. For. Res. 20:987-994.

Boyce, J. S. 1961. Forest pathology. McGraw-Hill Book Co., Inc., New York. 572 pp.

Carlson, C. E. and N. W. Wulf. 1989. Silvicultural strategies to reduce stand and forest susceptibility to the western spruce budworm. USDA Forest Service, Ag. Hand. 676. 31 pp.

Carlson, C. E., D. G. Fellin and W. D. Schmidt. 1983. Western spruce budworm in northern Rocky Mountain forests: a review of ecology, past insecticidal treatments and silvicultural practices. p. 76-103. *In:* Management of second growth forests, the state of knowledge and research needs. J. O'Loughlin and R. D. Pfister, eds., proceedings of a symposium May 14, 1982, Missoula, MT.

Carlson, C. E., W. C. Schmidt, D. G. Fellin and N. W. Wulf. 1984. Silvicultural approaches to western spruce budworm management in the northern U.S. Rocky Mountains. p. 281-300. *In:* Recent advances in spruce budworms research. C. J. Sanders, *et al.*, eds., proceedings of the CANUSA Spruce Budworms Research Symposium, September 16-20, 1984, Bangor, MA.

Filip, G. M., D. J. Goheen, D. W. Johnson and J. H. Thompson. 1989. Precommercial thinning in a ponderosa pine stand affected by Armillaria root disease: 20 years of growth and mortality in central Oregon. West. J. Appl. For. 4(2):58-59.

Fischer, W. C. and A. F. Bradley. 1987. Fire ecology of western Montana forest habitat types. USDA Forest Service, Gen. Tech. Rep. INT-223.

Franklin, J. F. 1989. Toward a new forestry. Amer. For. November-December. p. 37-44.

Franz, J. M. 1971. Biological and integrated control of pest organisms in forestry. Unaslyva, An International Review of Forestry and Forest Industries, 25(1). p. 45-56.

Gill, L. S. and F. G. Hawksworth. 1961. The mistletoes: a literature review. USDA Forest Service, Tech. Bull. No. 1242. 87 pp.

Gruell, G. E., W. C. Schmidt, S. F. Arno and W. J. Reich. 1982. Seventy years of vegetative change in a managed ponderosa pine forest in western Montana. USDA Forest Service. Gen. Tech. Rep. INT-130.

Gruell, G. E. 1983. Fire and vegetative trends in the Northern Rockies: interpretations from 1871-1982 photographs. USDA Forest Service, Gen. Tech. Rep. INT-158. 117 pp.

Hadfield, J. S. 1984. Root disease problems and opportunities in the interior Douglas-fir and grand fir forest types. *In:* Silvicultural managements strategies for pests of the interior Douglas-fir and grand fir forest types. p. 59-66. D. M. Baumgartner and R. Mitchell, eds., proceedings of symposium February 14-16, 1984, Spokane, WA. Washington State Univ. Coop. Ext., Pullman.

Hadfield, J. S. 1985. Laminated root rot: a guide for reducing and preventing losses in Oregon and Washington forests. USDA Pacific Northwest Region. U.S. Govt. Printing Office: 1985-596-837. 13 pp.

Hadfield, J. S., D. J. Goheen, G. M. Filip, C. L. Schmitt and R. D. Harvey. 1986. Root diseases in Oregon and Washington conifers. USDA Forest Service, Pacific Northwest Region, R6-FPM-250-86. 27 pp.

Hagle, S. K. and D. J. Goheen. 1988. Root disease response to stand culture. *In:* Proceedings of the future forests of the Intermountain West: a stand culture symposium. USDA Forest Service, GTR INT-243.

Hagle, S. K., G. I. McDonald and E. A. Norby. 1989. White pine blister rust in northern Idaho and western Montana: alternatives for integrated management. USDA Forest Service, GTR INT-261. 35 pp.

Haig, I. T., K. P. Davis and R. H. Weidman. 1941. Natural regeneration in the western white pine type. USDA, Tech. Bull. No. 767. 98 pp.

Marshall, R. 1928. The life history of some western white pine stands on the Kaniksu National Forest. NW Sci. 2(2):48-53.

Leopold, A. 1933. The conservation ethic. J. Forestry, May, p. 633-643. Reprinted J. Forestry 87(6):26-45. 1989.

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.

Morrison, D. J. 1981. Armillaria root disease: a guide to disease diagnosis, development, and management in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre, BC-X-203. 15 pp.

Roth, L. F., C. G. Shaw III and L. Rolph. 1977. Marking ponderosa pine to combine commercial thinning and control of Armillaria root rot. J. For. 75:644-646.

Spurr, S. H. and B.V. Barnes. 1980. Forest Ecology. John Wiley and Sons. 687 pp.

Stark, R. W. 1970. Integrated control, pest management or protective population management: Prac. 3rd Annual Northeastern Forest Ins. Work Conf., New Haven, CT.

USDA Forest Service. 1913. Working plan, Kaniksu National Forest. Unpublished report in the files, Idaho Panhandle National Forests Supervisor's Office, Coeur d'Alene, ID.

USDA Forest Service. 1979. Integrated Pest Management. Forest Service Manual, Chapter 2140-FSM 10/79, Amend 10.

USDA Forest Service. 1988. Forest health through silviculture and integrated pest management–strategic plan. US Govt. Printing Office 1988-576-488. 26 pp.

Wargo, P. M. and C. G. Shaw III. 1985. Armillaria root rot: the puzzle is being solved. Plant Disease 69(10): 826-832.

Watt, R. F. 1960. Second-growth western white pine stands. USDA Forest Service, Tech. Bull. No. 1226. 60 pp.

Wellner, C. A. 1984. History and status of silvicultural management in the interior Douglas-fir and grand fir forest types. *In:* Silvicultural managements strategies for pests of the interior Douglas-fir and grand fir forest types. D. M. Baumgartner and R. Mitchell, eds., proceedings of symposium February 14-16, 1984, Spokane, WA. Washington State Univ. Coop. Ext., Pullman.

Authors

James W. Byler
Plant Pathologist
USDA Forest Service, Region 1
TCPFM
P.O. Box 7669
Missoula, MT 59807

Sara Zimmer-Grove
Resource Forester
USDA Forest Service
Black Hills National Forest
Bearlodge Ranger District
Sundance, WY 82729

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.