OREGON STATE UNIVERSITY EXTENSION SERVICE

Managing Insects and Diseases of Oregon Conifers

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Contents

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Chapter 1

Introduction

This management guide is designed to help field foresters, loggers, and landowners deal with the major insect pests and diseases of conifers in Oregon forests. We do not attempt to cover every insect and disease, only the most common and economically important. Our focus is on silvicultural techniques; we discuss chemical and biological controls only when relevant or commonly used. We also note that all insects and fungi are not bad—in fact, many of them benefit forests in innumerable ways.

To determine appropriate management action in a certain disease or pest situation:

- Survey the property and map the general distribution of the problem.
- Evaluate species composition, stand density, and structure.
- Describe your overall forest management plan, including your desired economic and wildlife benefits.
- Develop a proactive management plan that integrates the spatial distribution of the problem and your long-term goals for the site.

Here is an example of how to use this field guide:

You are considering a 40-year-old Douglas-fir stand for commercial thinning. You discover laminated root rot has created canopy gaps. Dead and dying trees surround the gaps, and logs and windthrown trees are in the gaps.

Go to Chapter 6, on root diseases. Table 6-2 (page 70) notes that coastal Douglas-fir is highly susceptible to the disease. Table 6-3 (page 75) lists management strategies, which include excavating stumps or thinning to decrease root contacts. (Planting to favor resistant species

The companion guide

Management guidance in this book complements *Field Guide to the Common Diseases and Insect Pests of Oregon and Washington Conifers* (Goheen, E.M., and E.A. Willhite, 2006, USDA Forest Service), which is an identification guide. Throughout this publication, we refer to specific pages in Goheen and Willhite (G&W) for help in identifying a pest and gauging its importance. Also see the identification key on pages 1–12 of the field guide. Ordering information for Goheen and Willhite is on page 131.

is an especially important alternative, but that won't help right now because new planting won't occur until after final harvest.)

Survey the site and determine the extent of the problem. As noted in Chapter 6, if your stand has only one or two root-disease centers and less than 5 percent of the stand affected, you might be safe in ignoring the problem.

Since you are considering commercial thinning, you'll want to learn more about:

- Partial cutting (page 71)
- Sanitation–salvage cutting (page 71)
- Clearcutting and regeneration (page 72)
- Uneven-aged management (page 73)
- Prescribed burning (page 73)
- Stump excavation (page 74)
- Chemical control (page 74)

Management considerations discussed above are from a strictly economic perspective. If, however, wildlife management is a goal for the site, root-disease centers can play interesting roles in improving habitat. For example, forest gaps that root disease creates in 20- to 40-year-old westside conifer forests usually improve forage on the forest floor, because more light penetrates the canopy. Also, dead and dying trees provide habitat for cavity-nesting birds and mammals as well as food for insect-eating woodpeckers, nuthatches, and chickadees. Down woody debris can improve habitat for small mammals and amphibians, while pileated woodpeckers will forage on carpenter ants that inhabit down wood. Therefore, base the management of forest insects and diseases on your objectives.

Other resources[1]

For an overall silviculture, ecology, and management perspective on the unique eastside forests of Oregon, see *Ecology and Management of Eastern Oregon Forests*. This manual has much information on specific stand management by forest type.

For management of insects, weeds, and diseases, including registered chemical controls, see the current editions of the *Pacific Northwest Insect Management Handbook*, the *Pacific Northwest Plant Disease Management Handbook*, and the *Pacific Northwest Weed Management Handbook*. Each volume is revised and reissued annually.

A diagnostic clinic for plant diseases and insect identification

[1] For details and ordering information, see Chapter 11, starting on page 129.

operates from the OSU campus, in Corvallis. Forms for submitting samples, fee information, and other details are online at http://plant-clinic.bpp.oregonstate.edu/.

Nursery and seedling pests and Christmas tree problems are not addressed specifically in this guide, but many insects and diseases described in these chapters do affect Christmas trees as well. OSU Extension foresters in county offices can help, also. For an excellent guide to Christmas tree health, see *Christmas Tree Diseases, Insects, and Disorders in the Pacific Northwest: Identification and Management*.

Hazard- and danger-tree problems are not addressed in this guide, though attacks by many pests discussed in this guide do result in hazard trees.

Forest protection against abiotic threats (weather, drought, nutrition, etc.) and vertebrate pests (deer, elk, gophers, bear, etc.) is not discussed in this book, nor do we discuss invasive insects and diseases currently threatening Oregon but not yet established, such as the gypsy moth.

Photo: Lynn Ketchum, © Oregon State University

Sunlight filters through an Oregon forest.

CHAPTER 2

Bark Beetles, Wood Borers, and Ambrosia Beetles[2]

Introduction to boring and mining insects

Bark beetles

Bark beetles (Table 2-1, page 11) are small, native insects that can do a lot of damage if not managed. Factors such as drought, overstocking, defoliation, and root disease can reduce tree vigor and increase tree and stand susceptibility to attacks. Although direct control—such as hand felling and burning, chemicals, and pheromone technologies (for some species)—are options, silviculture and stand management are the primary management tools. Bark beetles generally are attracted to stressed trees growing at higher densities, although some species target older, larger trees. This chapter provides a framework for control strategies and making management decisions.

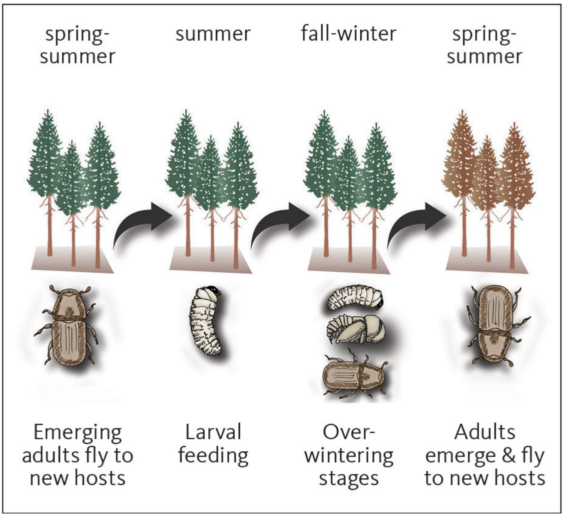

Illustration: Gretchen Bracher

Figure 2-1. Most bark beetles have a 1-year life cycle.

Bark beetle life cycles and management implications

Bark beetles spend most of their lives between the bark and sapwood. Generally, for beetles that have a 1-year life cycle, adult beetles emerge from overwintering sites in spring or early summer, fly to a host tree, tunnel through the bark, construct an egg gallery in the cambium area, and lay their eggs. Larvae feed through the summer and fall; overwinter as larvae, pupae, or adults; complete development the next spring; and emerge to seek new hosts (Figure 2-1).

[2] Goheen and Willhite, 14–61

Bark beetles kill individual trees here and there in the forest but more commonly attack clumps of trees (Figure 2-2, page 16) using a mass-attack pheromone communication system to marshal large numbers that overcome their hosts.

Most bark beetles in Oregon have a 1-year life cycle, but some take up to 2 years (e.g., the spruce beetle) and others have multiple generations within a year (e.g., western pine beetle and *Ips*). Knowing the beetle's life cycle helps you decide, for example, when to remove infested trees or logs before beetles emerge, when to spray individual trees before beetles attack, and when it's safe to transport beetle-killed firewood from forest to home.

In most cases, trees attacked by bark beetles do not show crown (foliage) symptoms until the spring after attack; then, foliage changes rapidly from green to yellow to red and, finally, to brown. Once foliage turns red, bark beetles have already left the tree or will very soon. Once beetles "fly the coop," removing affected trees has no effect on beetle populations.

A sanitation operation removes beetle-killed trees before beetles leave the tree. This step is most effective when treating large areas, preferably at the watershed level.

The key is to know which trees are infested before crown symptoms appear. To find out, you need to know the flight period and life cycle of the beetle as well as the signs and symptoms of attacked trees. Other than fading crowns, each beetle species and its host has particular signs and symptoms (G&W 16–55). Some general clues to look for are:

- Boring dust on the main trunk or base of the tree
- Beetles or larvae under bark
- Galleries under bark
- Fresh pitch tubes (on pines) or resin streams (on Douglas-fir) on the outside bark
- Sometimes, evidence of woodpecker feeding on bark

Beetle behavior and risk of attack

Low- or background-level populations of bark beetles are always present. These populations seek out and are supported by scattered host trees weakened by factors such as root disease or wind damage in the forest. While small windthrows, snow breakage, and logging or thinning debris can foster local, brief build-ups of Douglas-fir beetle, spruce beetle, and *Ips* spp., epidemics typically are triggered by landscape-level conditions such as drought, defoliation, large-scale windthrow, or overstocking (often caused by fire suppression).

Text continues on page 16

Table 2-1. Common bark beetles, wood borers, and ambrosia beetles: Hosts, key identifiers, flight periods, and distribution and severity.

Beetle	Major host(s)	Key identifiers	Flight period	Distribution and severity
Ambrosia beetles *Gnathotrichus* spp., *Trypodendron* spp.	Most conifers	▪ Fine, whitish boring dust in bark crevices ▪ Pinhole tunnels in sapwood	March–October	Throughout Oregon, but damage is greater in wetter coastal areas. Beetles do not kill live trees but can extensively degrade wood quality.
Cedar bark beetles *Phloeosinus* spp.	Native junipers, cedars, coast redwood, giant sequoia	▪ Fine orange-red boring dust on bark ▪ Galleries under bark tend to be longitudinal but can also be randomly oriented and irregularly shaped ▪ Attacks on stem, tops, and branches	May–September	Throughout Oregon where hosts grow. Usually a secondary pest; however, they can kill trees weakened by drought or root disease.
Douglas-fir beetle *Dendroctonus pseudotsugae*	Douglas-fir	▪ Attacks on larger trees (> 14 inches DBH, except > 10 inches in SW Oregon) ▪ Red-orange boring dust on bark ▪ Pitch streams high on stem ▪ Associated with root disease	May–September	Throughout Oregon. Outbreaks in western Oregon are associated with extensive windthrow. Eastern Oregon outbreaks occur after windthrow, defoliator outbreaks, or extended drought.

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Table 2-1. (continued) Common bark beetles, wood borers, and ambrosia beetles: Hosts, key identifiers, flight periods, and distribution and severity

Beetle	Major host(s)	Key identifiers	Flight period	Distribution and severity
Douglas-fir engraver *Scolytus unispinosus* and *S. monticolae*	Douglas-fir	▪ Longitudinal egg galleries etched or lightly etched into wood ▪ Dead tops of mature trees, smaller saplings, or pole-size trees	April–July	Throughout range of host. Secondary pest, but can kill trees weakened by drought, root disease, or defoliation. During drought, can build up in slash or windthrow and kill nearby trees.
Douglas-fir pole beetle *Pseudohylesinus nebulosus*	Douglas-fir	▪ Longitudinal egg galleries etched or lightly etched into wood ▪ Dead tops of mature trees, smaller saplings, and pole-size trees	April–July	Throughout range of host. Secondary pest, but can become more aggressive when trees are weakened by drought, root disease, or defoliation. During drought, can build up in slash or windthrow and kill nearby trees.
Fir engraver *Scolytus ventralis*	White fir, grand fir, Shasta red fir, noble fir	▪ Horizontal egg gallery etched in wood ▪ Reddish-brown boring dust in bark crevices ▪ Associated with root disease ▪ All sizes of trees and tops killed	June–September	Throughout Oregon. Increased tree kill is associated with root disease, drought, wounding, overstocking, and defoliation.

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Table 2-1. (continued) Common bark beetles, wood borers, and ambrosia beetles: Hosts, key identifiers, flight periods, and distribution and severity

Beetle	Major host(s)	Key identifiers	Flight period	Distribution and severity
Flatheaded wood borers Family Buprestidae; many species	All conifers	▪ Larval mines under bark, sometimes continuing into wood ▪ Winding galleries, packed with fine boring material, laid down in concentric crescents	May–September	Throughout Oregon. Usually a secondary pest, but can degrade wood and log quality.
Flatheaded fir borer *Phaenops drummondi*	Douglas-fir and true firs	▪ No larvae in sapwood ▪ Pitch streams on Douglas-fir boles	May–September	Can kill more trees during drought periods, especially in southwest Oregon and in the Willamette Valley. Drier fringe areas are particularly vulnerable.
Horntails (wood wasps) Several species in the family Siricidae	Numerous conifers and hardwoods	▪ Larvae bore into sapwood and heartwood ▪ Large, perfectly round exit holes ▪ Larvae with a spine on their posterior	May–September	Throughout Oregon. Nonaggressive, attacking only dead and dying trees, especially recently fire-killed trees and windthrow. Can degrade logs milled for lumber. After emerging, do not reinfest milled lumber.
Mountain pine beetle *Dendroctonus ponderosae*	Lodgepole pine, ponderosa pine, sugar pine, western white pine	▪ Quarter-size pitch tubes on outside of bark ▪ Trees > 8 inches DBH typically attacked ▪ Reddish boring dust	July–September	Throughout Oregon. Can be an aggressive tree killer during outbreaks. Stand susceptibility closely tied to high stocking levels and tree age. Widespread epidemics are characteristic of lodgepole pine.

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Table 2-1. (continued) Common bark beetles, wood borers, and ambrosia beetles: Hosts, key identifiers, flight periods, and distribution and severity

Beetle	Major host(s)	Key identifiers	Flight period	Distribution and severity
Pine engravers Pine engraver beetle (*Ips pini*) and California fivespined Ips (*Ips paraconfusus*)	Most common in ponderosa, lodgepole, and Jeffery pines	▪ Attacks commonly on small trees and on tops of larger trees ▪ Groups of dead trees adjacent to fresh slash or winter damage ▪ Foliage can begin fading within a few weeks ▪ Woodpecker feeding (shaved bark)	April–September (up to three generations per year)	Pine engraver throughout Oregon, California fivespined ips west of the Cascade mountains predominantly. Population levels closely tied to quantity of fresh pine slash or windfalls and to drought. Pine engravers typically kill small trees. Pines on poorer sites are more susceptible.
Red turpentine beetle *Dendroctonus valens*	Ponderosa pine, lodgepole pine	▪ Large, resinous pitch masses or small, granular resin-soaked pitch tubes ▪ Pitch tubes on base of tree bole or on stumps ▪ Very common on wounded and fire-injured trees	May–September	Throughout Oregon. Not very aggressive; attacks weakened trees, but usually doesn't kill trees. During drought or repeated attacks, sometimes can kill trees but more commonly weakens trees, increasing susceptibility to other bark beetles.
Roundheaded wood borers Family Cerambycidae; many species	All conifers	▪ Larval mines under bark may continue into the wood ▪ Winding galleries loosely packed with coarse, angular boring material	May–September	Throughout Oregon. Usually a secondary pest; however, it can degrade logs to be milled.

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Table 2-1. (continued) Common bark beetles, wood borers, and ambrosia beetles: Hosts, key identifiers, flight periods, and distribution and severity

Beetle	Major host(s)	Key identifiers	Flight period	Distribution and severity
Spruce beetle *Dendroctonus rufipennis*	Engelmann spruce, Sitka spruce	▪ Larger trees attacked, except during outbreaks ▪ Red-brown boring dust ▪ Green needle drop ▪ Woodpecker feeding (shaved bark)	May–July	Throughout Oregon. In western Oregon, tree mortality is limited. In eastern Oregon, epidemics may develop after windthrow events or drought.
Western pine beetle *Dendroctonus brevicomis*	Ponderosa pine	▪ Reddish boring dust ▪ Small pitch tubes ▪ Spaghetti-like, winding egg galleries under bark ▪ Woodpecker feeding (shaved bark)	June–August (may have two generations)	Throughout Oregon. At low population levels, they breed in declining trees or windthrow. During drought, they can become aggressive. Outbreaks are most commonly associated with large old growth and overcrowded second growth.
Western balsam bark beetle *Dryocoetes confusus*	Subalpine fir	▪ Starfish gallery pattern under bark ▪ Flagging and dead tops after branch attacks ▪ Tree mortality	Variable but likely June–August (may take 2 years to develop); may be more than one flight period	Follows subalpine fir distribution. Damage associated with drought, winter injury, and other biotic agents. Impacts on tree may be associated with pathogenic tree fungus. May cause slow decline and strip attacks.

Certain bark beetle species prefer certain tree bole diameters, a fact that can help you evaluate stand risk and your management options. For example, overstocked stands of small-diameter Douglas-fir are at lower risk from Douglas-fir beetle, because it prefers larger trees (Table 2-1, page 11).

Figure 2-2. Bark beetles can kill single trees but more typically kill groups of trees.

A given type of bark beetle generally attacks just one or a few host species. Table 2-1 shows key hosts, identifiers, flight periods, and distribution and severity in Oregon for some important bark beetles, wood borers, and ambrosia beetles.

Wood borers

Wood borer subgroups are:

- Flatheaded wood borers (metallic wood-boring beetles)
- Roundheaded wood borers (long-horned beetles)

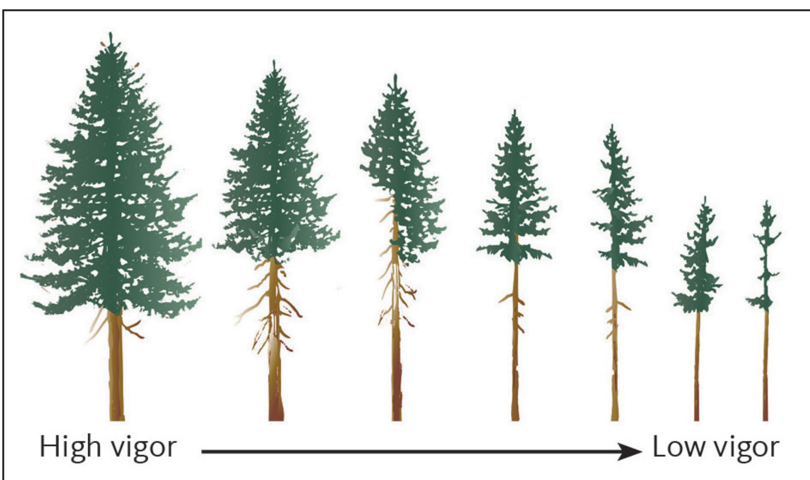

Illustration: Gretchen Bracher

Figure 2-3. Crown quality is a good measure of tree health and, therefore, of susceptibility to bark beetles.

- Horntails (wood wasps)

Larvae of flatheaded borers have a flat head; adults have a bullet shape and a metallic sheen. Roundheaded larvae heads are round, and the adult's antennae are longer than its body (G&W 56–61). Wood wasp larvae bore into the wood of dead and dying trees and potentially can degrade lumber quality of salvaged timber.

Many species of wood-boring beetles and wasps are found throughout Oregon on all conifers. Some wood borers mine only under bark; most mine wood, however, and thus degrade wood quality (Table 2-1, page 11).

Generally, wood borers do not kill healthy trees but develop in trees damaged or killed by fire, insects, disease, wind, or other factors. However, the flatheaded fir borer can be more aggressive. In southwest Oregon, extensive Douglas-fir mortality from this insect is associated with harsh sites or drought, mostly on sites below 3,500 feet.

Wood wasps are attracted to recently fire-damaged trees as well as windthrow; it is common to see female wasps with their long ovipositor laying eggs on smoldering trees. The flatheaded fir borer is also attracted to recently fire-damaged trees. For the most part, the primary role of wood borers is to recycle wood back into the soil.

Ambrosia beetles

Ambrosia beetles live under bark but not in the same area as bark beetles; instead, ambrosia beetles bore tiny holes into the wood (Table 2-1, page 11). They are not aggressive tree killers but extensively degrade the wood. Adults carry an ambrosia fungus that they nurture in their tunnels, providing food for adults and larvae. The fungus stains the wood, contributing to degradation. Beetles normally are found in windthrown timber, felled and bucked logs, and dying or recently dead trees.

Management strategies for specific pests[3]

Bark beetles

Western pine beetle

Tree mortality is associated with poor vigor, slow-growing older trees, dwarf mistletoe, drought, trees injured by lightning or fire, and root disease. There have been no thinning studies for western pine beetle, but thinning has been found to be generally beneficial, except during periods of prolonged droughts.

Management strategies in old-growth forests include:

- Remove large, weakened trees; for example, those with thin foliage, flat-top crowns, and a live-crown ratio (proportion of total tree height in live crown) of less than 30 percent.
- Remove infested trees (sanitation) before beetles emerge.

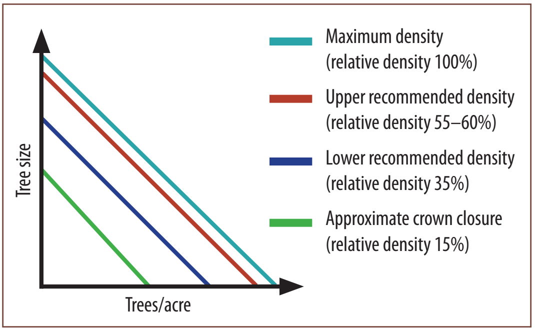

Figure 2-4. Relationship between density and tree diameter and its effect on stand productivity and tree vigor. Stands with densities between the upper and lower recommended density lines will be productive and at low risk for bark beetle attack.

- Minimize tree damage, such as from logging, fire, or road construction.

Management strategies in second-growth stands include:

- Thin overstocked stands, retaining trees with high vigor (Figure 2-3, page 16).
- Keep densities below the self-thinning threshold, i.e., below the upper recommended density line in Figure 2-4.
- When thinning pine, manage slash to prevent *Ips* population build-up and residual stand damage.

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[3] Refer to *Ecology and Management of Eastern Oregon Forests: A Comprehensive Manual for Forest Managers* (Manual 12) for density management information for the forests of eastern Oregon. Check with your local professional foresters for density management guidelines in western Oregon.

[3] Fettig, Christopher J.; Klepzig, Kier D.; Billings, Ronald F.; Munson, Steven A.; Nebeker, Evan T.; Negron, Jose F.; Nowak, John T. 2007. The effectiveness of vegetation management practices for prevention and control of bark beetle infestations in coniferous forests of the western and southern United States. *Forest Ecology and Management*. 238 (1-3): 24-53.

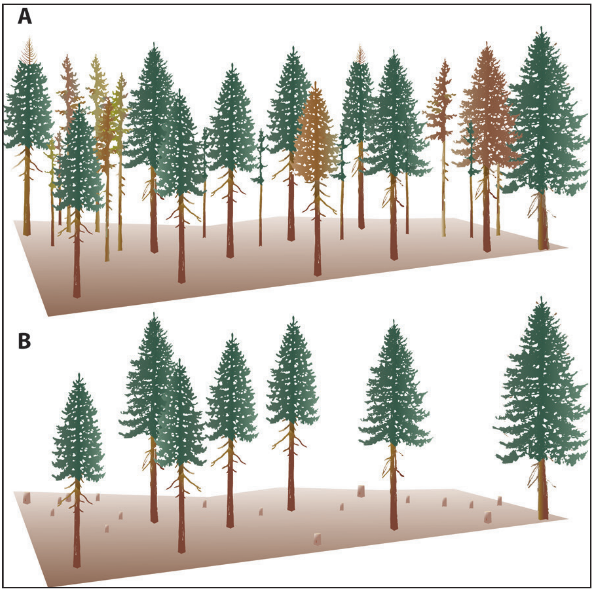

Illustration: Gretchen Bracher

Figure 2-5. Salvage and sanitation are stand treatments to remove trees that are dead or dying, infested, or weak (A) and therefore susceptible. Removing these trees (B) lowers beetle populations and frees up more growing space, which will improve vigor in remaining trees.

Mountain pine beetle in ponderosa pine forests

Thinning studies in ponderosa pine forests have shown reduced mortality, even during mountain pine beetle outbreaks, except when the area thinned is small and surrounded by extensive areas of unmanaged forest with high populations of beetles. Current thinking is that thinning increases tree vigor, defenses, and growth and changes stand physical characteristics in ways that interfere with bark beetle host-finding ability and mass-attack success. Thinning has shown good results for lowering beetle risk, especially in drier forests.

Management strategies include:

- Prioritize stands: first, thin overstocked, large-diameter stands (typically, 8 inches DBH and larger) and higher value stands.
- Help prevent attacks by keeping stand densities below the upper recommended density line (Figure 2-4) to decrease individual tree stress, reduce attractiveness to mountain pine beetles, and give the stand room to grow. Rate of mortality increases with increasing stocking. Stocking rates vary by site capacity.
- If bark beetles are active in the stand, complete salvage and sanitation operations before the peak of the beetles' flight period (Table 2-1, page 11, and Figure 2-5).
- In patchy stands, high-density centers are susceptible to beetle attack; remember to thin them.

- Use an increment borer to monitor leave-tree diameter growth after thinning to see whether the thinning response meets your goals.
- Tree ring growth can also indicate an individual pine tree's risk of infestation. If growth falls below 0.75 inch per decade (more than 13 rings per inch) or if the last 5-year increment is significantly narrower than the previous 5 years', you are looking at a high-risk tree.

Mountain pine beetle in lodgepole pine forests

Stand susceptibility increases because of factors such as increased stand densities, larger tree diameter, stand age, low tree vigor and growth rates, and phloem thickness. Tree size seems to be the most reliable predictor of lodgepole stand susceptibility to this beetle. Stands with an average DBH of more than 8 to 10 inches are more susceptible than stands with smaller trees. Thinning can reduce mountain pine beetle activity in overstocked stands with good crowns, but is less effective during an ongoing epidemic.

In Oregon, management strategies include:

- Make patch cuts to increase diversity of age classes (tree sizes) across the landscape. This works better in larger ownerships, but owners of smaller tracts could adopt this approach cooperatively, too.
- If the stand includes young and old age classes, and if the younger class is healthy and has good live-crown ratios (above 30 percent), then use a diameter-limit cut to remove the older, larger trees in the overstory.
- In mixed-species stands, thin out most susceptible-size lodgepole and declining trees with low vigor.
- On better sites, thin young stands. Older stands typically have poor live-crown ratios, so leave trees won't respond as well to thinning. Also, lodgepole pine tends to have a shallow root system and is more susceptible to windthrow on thinned sites.

Mountain pine beetle in sugar pine and western white pine forests

Large-diameter sugar pine and western white pine are highly susceptible to mountain pine beetle, especially when these light- and space-loving trees become crowded by grand or white fir, as is associated with fire suppression. Reducing stand density around these large individuals is thought to improve vigor, reduce drought stress, and therefore limit the potential for beetle kill.

White pine blister rust (Chapter 9) is a major tree-weakening factor for sugar pine and western white pine. Trees with branch and crown loss

Slash management for pine engraver beetles

Managing slash and winter breakage is the key to minimizing damage from *Ips*:

- *Log or thin after late July and before January. Slash dries out enough that it does not provide good host material for beetles the following spring.*
- *If possible, do not log or thin pine in winter or spring unless you use or dispose of slash greater than 3 inches in diameter. Dispose of slash by burning, chipping, or dozer trampling or by lopping into smaller pieces and scattering it in forest openings.*
- *If you generate pine slash in winter or spring, create a "green chain"—a continuous supply of green slash throughout the second-generation flight period (and beyond, if more generations are expected), which provides the beetles an alternative to standing trees.*
- *Or, build very large slash piles: about 20 feet across and 10 feet deep. If piles are large enough, interior pieces won't dry out because they're shaded. In spring, beetles attack the outside layers of the pile; in July, when they seek new host material, they will migrate deeper into the pile instead of flying to nearby standing trees. (This technique has not been widely tested.)*
- *To kill beetles in slash or firewood, cover the piles completely with clear plastic and bury the edges of the plastic. Make sure the covered piles are not shaded.*
- *Don't stack fresh pine firewood close to live pines.*

due to the rust are at risk of attack. Planting disease-resistant stock is recommended to reduce incidence of white pine blister rust infection and therefore reduce mountain pine beetle risk when trees reach susceptible diameters.

Pine engraver beetles

Tree and stand damage from the pine engraver and California fivespined ips is closely tied to green slash, drought, and overstocking. Pine debris from winter or spring logging, a precommercial thinning, or winter damage is a ready breeding ground.

The life cycle begins when adults overwinter in duff and under bark. Adults emerge in spring and infest winter breakage, blowdown, and slash. A brood develops May–June, and a second generation of adults emerges in late June or July and can attack standing trees. A third generation is possible, especially farther south, if warm temperatures continue late into fall.

In trees under stress, elevated beetle populations can overcome and kill nearby small trees and tops of larger trees. Drought increases stand vulnerability and can extend the period of tree mortality. In most cases, expect most mortality in the year the *Ips* population builds up. However, if host material is available the next winter or spring, or if droughty conditions develop, anticipate mortality the next year. *Ips* can be significant in fire-injured hosts.

Red turpentine beetle

This beetle seldom kills trees; however, repeated attacks can weaken trees and heighten their risk of attack from mountain pine beetle, western pine beetle, and *Ips*. Keeping tree vigor high is the key to preventing attacks. Red turpentine beetle attacks usually indicate that a tree is under stress and that the tree or the stand it's in could benefit from a vigor-enhancing treatment.

Management strategies include:

- Avoid compacting soil or injuring the trunk and roots.
- Maintain good spacing between trees.
- When thinning, remove low-vigor, diseased, and weakened trees.
- Do not pile freshly cut pine firewood or branches against green trees, because the red turpentine beetle is strongly attracted to fresh resin.
- After logging, remove damaged trees, especially along skid trails.

Douglas-fir beetle and spruce beetle

Small populations persist in scattered windthrown, injured, or diseased trees. Epidemics are triggered by windstorms, fire (Douglas-fir beetle only), or defoliation. These beetles normally do not attack trees with stems smaller than 12 to 14 inches DBH. Westside forests typically do not require thinning for Douglas-fir beetle; however, it is considered beneficial on the eastside.

In Douglas-fir, risk is higher in stands:

- Larger than 12 to 14 inches average DBH (10 inches in southwest Oregon)
- Above the self-thinning density level (i.e., overstocked) in eastside forests
- With more than 50 percent Douglas-fir
- With many shaded stems

Typically, stands with more than three to five large-diameter windthrown trees per acre, often produced in larger events, are needed to increase populations of beetles to the point that they can kill live trees the following year.

For eastside spruce, risk is higher in stands:

- On well-drained sites in creek bottoms
- Where DBH averages 16 inches and basal area/acre average 150 square feet or more
- With more than 65 percent spruce

Management steps include:

- Salvage and process Douglas-fir and spruce blowdown in fall and winter no later than the spring after infestation (see "Managing blowdown," page 24). Identify and remove nearby infested trees.
- Early in the outbreak when beetle populations are high, use "trap trees." Cut trees in late fall, winter, or early spring before beetle flight. Fresh down trees attract dispersing beetles. Once logs are infested, remove them before beetles emerge the next spring. Later in the outbreak, when beetle populations are very high, trap trees become ineffective.
- To lower risk, keep the stand below the upper recommended density in eastern Oregon.

Douglas-fir engraver and Douglas-fir pole beetle

These beetles kill sapling- and pole-size Douglas-fir as well as the tops of mature trees. The beetles are secondary pests and generally attack only weakened trees.

Often they're associated with trees killed by the Douglas-fir beetle or flatheaded fir borer. Engraver beetles and pole beetles can become much more common tree killers during periods of drought, especially where large amounts of slash or windthrow have allowed populations to expand and move to nearby trees.

Management steps include:

- Keep trees and stands vigorously growing with timely thinning.
- Remove low-vigor trees in selective harvests.
- During droughts, try to schedule thinnings in late summer and fall, after beetle flight.

Fir engraver

For grand fir and white fir, risk of mortality from fir engraver increases as average annual precipitation decreases. Risk is low at 40 inches or more annually, medium at 30 to 40 inches, high at 25 to 30 inches, and extreme below 25 inches.

True firs have low tolerance for moisture stress. Prolonged drought will profoundly affect their distribution and susceptibility to fir engraver attacks.

Managing blowdown for Douglas-fir and spruce beetles

Douglas-fir beetle

Douglas-fir beetle (Dfb) often is associated with tree mortality after large wind storms (Figure 2-6). Outbreaks usually are local and can persist for 2 to 3 years. Beetles attack down trees the spring after a windthrow event. It takes 1 year for a brood to develop and adults to disperse. Generally, if three or more trees greater than 14 inches DBH (10 inches in southwest Oregon) are downed per acre, beetle populations will be large enough to attack standing trees. Drought increases the probability that standing trees will be killed.

Photo: Glenn Ahrens, © Oregon State University

Figure 2-6. Douglas-fir beetles attack down trees the spring after a windthrow event.

To prevent beetle population increases and to limit wood deterioration, salvage blowdown as soon as possible but not later than beetle emergence the next spring. Down trees less than 10 to 12 inches DBH are not good brood logs. Leaving moderate amounts of material this size can provide structure and substrate for wildlife and will build soil organic matter without risking large beetle build-ups.

Salvaging during the spring that beetles infest down trees will reduce log deterioration from wood borers and sap rots, especially for logs less than 24 inches DBH. On wetter sites, however, salvage may have to be delayed until summer to avoid site damage, such as soil compaction.

If salvage cannot be done within a year after infestation, because of access limitations or other reasons, consider using MCH, an antiaggregative pheromone, to protect down trees and/or standing, high-value trees the following year (see page 29).

Spruce beetle (westside)

Blowdown of Sitka spruce is considered a low risk for beetle population build-ups and standing tree mortality.

Spruce beetle (eastside)

Windthrown Engelmann spruce can be cause for concern. Although scattered blowdown maintains spruce beetle populations, most epidemics in standing timber are triggered by windthrow events.

Beetles can fly any time from May to October, but most of the population disperses in spring. Life cycles can be more than 1 year; however, prudent salvage timing would be to remove infested fall or winter blowdown within 1 year after infestation. MCH has been effective in preventing attacks on down logs and could be considered an alternative to salvage.

Management steps include:

- For pure true fir stands on good sites, manage stand densities at 25 to 55 percent of maximum stocking (Figure 2-4, page 18). This can be less effective during periods of persistent drought, root disease areas and on drier sites. Although thinning studies as a management tool for bark beetles have not been done, thinning is generally applied with good results except during periods of drought, defoliation, and root disease.
- On high- to extreme-risk sites, convert to or favor species such as ponderosa pine that better tolerate drier conditions. Grow grand and white firs only on more productive sites. Even where true firs appear to be growing reasonably well, promote mixtures with larch, lodgepole pine, Douglas-fir, ponderosa pine, or other species appropriate to the site to buffer stands against fir engraver mortality.
- In stands of grand or white firs, root disease increases risk from fir engraver. Convert these stands to species less susceptible to root disease and follow guidelines for managing root disease (see Chapter 6).
- In true firs, defoliation also can increase fir engraver risk. Follow stand-management guidelines in Chapter 3 to lower defoliator risk.

Western balsam bark beetle

The western balsam bark beetle is the most common beetle associated with subalpine fir, where it can cause branch death and top dieback by strip attacks or kill trees outright. Multiple attacks may cause a slow decline of the tree. The beetle is often associated with drought and winter injury as well as with other biotic agents such as balsam woolly adelgid, root diseases, and defoliators. A pathogenic fungus transported by the beetle, *Ceratocystis dryocoetidis*, and perhaps other fungi may cause lesions and kill the tree independently of the beetle. Higher-elevation subalpine fir is typically unmanaged.

Cedar bark beetles

Cedar bark beetles are secondary and typically associated with weakened, felled and dying trees; however, during drought cycles they can become more aggressive, kill more trees, and kill apparently healthy trees. To keep damage from this beetle low, manage root disease, prevent off-site plantings and otherwise use silvicultural treatments such as thinning to maintain high tree vigor.

Wood borers and ambrosia beetles

Flatheaded fir borer

In southwest Oregon, the flatheaded fir borer is associated with Douglas-fir mortality at elevations below 3,500 feet and where annual precipitation is less than 40 inches.

Douglas-fir may not be appropriate for some sites where Oregon white oak is dominant and/or soils are very coarse and droughty. Thinning may not increase resistance of Douglas-fir in these marginal sites.

Management steps include:

- On warm, dry sites in Oregon, regenerate or favor pine during thinning.
- Avoid disturbing trees when clearing for or constructing homes. For example, avoid backfilling over roots, compacting soil in the root zone, and making road cuts that damage roots.
- Remove fire-damaged trees at high risk of attack; i.e., trees with damage to more than 50 percent of the crown or 25 percent of the cambium.

Roundheaded wood borers, most flatheaded wood borers, and horntails

These insects facilitate the breakdown of dead or dying trees and can infest felled timber; however, they are not aggressive tree killers and do not emerge and attack healthy trees. No species in Oregon reinvades the same wood from which it emerged.

Management steps include:

- To prevent degraded log quality, process timber and logs within 1 year after tree death.
- Remove down timber promptly, to reduce damage to wood.

Ambrosia beetles

Management steps include:

- When beetles are flying, move logs from woods to mill soon after cutting.
- Avoid storing fall- and winter-cut logs.
- Store logs in ponds or water-sprinkled storage decks.
- Store green lumber away from log storage areas, debris, and forest edges.
- Locate sort yards away from forested areas; remove potential breeding and overwintering sites near sort yards.

Silvicultural control

Managing bark beetles in infested stands

If stands are heavily infested:

- Salvage dead and dying trees and convert to a vigorous, young stand with planting or natural regeneration.
- Regenerate with tree species suited to the site's aspect, elevation, root-disease presence, and soils. Plant seedlings grown from seed collected within the appropriate seed zone and elevation.
- Encourage species and stand diversity across the landscape.

If stands are lightly or moderately infested:

- Salvage dead and dying trees and sanitize the rest of the stand by removing high-risk trees. If trees still are too crowded, thin overstocked areas according to local stocking-level guides (for guides, contact the OSU Forestry and Natural Resources Extension agent who serves your area).

Managing bark beetles in uneven-aged stands

General guidelines are:

- For group selection, treat clumps as small, even-aged stands and thin accordingly.
- Uneven-aged stands may be inherently more resistant to beetles because many beetle species prefer larger trees. For example, trees smaller than 8 to 10 inches DBH in uneven-aged stands of pine or Douglas-fir are at lower risk from mountain pine beetle or Douglas-fir beetle. Larger trees may be susceptible to attack while smaller trees are not.
- Though smaller trees use fewer site resources than larger trees,

overstocking smaller trees in uneven-aged stands can lower larger trees' vigor. Include all size classes in your thinning program, and use spacing that reflects the resource needs of each size class.

- In unmanaged, uneven-aged stands, bark beetles can maintain small but viable populations by killing a few weakened, larger trees each year. So, it's important to keep all size classes vigorous.
- Dwarf mistletoe and root disease problems are more difficult to manage—and thus elevate beetle risk—in uneven-aged stands.
- Be careful in thinning uneven-aged pine forests. If you're creating thinning slash larger than 3 inches in diameter, follow *Ips* slash management guidelines (page 21).

Managing fire-damaged trees

Bark beetles, wood borers, and ambrosia beetles attack fire-damaged trees. Bark beetles kill them; wood borers and ambrosia beetles degrade their wood. Most infestation and death will occur by the end of the growing season after the fire (i.e., 1 year after the fire). Thus, it is important to identify and salvage all infested and high-risk trees promptly.

For help in assessing trees' potential for survival following a fire, contact the OSU Forestry and Natural Resources Extension agent or Oregon Department of Forestry stewardship forester who serves your area for guides that work in your area.

Managing root-disease areas

Bark beetle mortality may indicate a root disease issue. If so, any treatment strategy should manage the underlying problem:

- Follow management guidelines for root disease (see Chapter 6, page 67).
- Convert to resistant species to create more tolerant stands, improve tree vigor, and lessen susceptibility to bark beetles (Table 6-2, page 70).
- In stands with Armillaria root disease, tree stress can aggravate the impacts of root disease and can increase susceptibility to bark beetles. Thinning may help as long as soil compaction and tree wounding are minimized.

Chemical and biological controls

Pheromones

Bark beetles use pheromones to communicate location and to regulate population density on host trees. Attraction pheromones are released when the first attackers bore through the bark. As male and female beetles pair up during the mass attack, they release an antiaggregative pheromone to signal incoming beetles that the tree is occupied.

Both attraction and antiaggregative pheromones are potential management tools. Attraction pheromones can monitor beetles and draw them into trees or stands for trapping and removal. Although promising, this technology is still young and not easy for woodland owners to apply. Use attractant pheromones with caution and only after consulting with entomologists or pheromone technology specialists. It is easy to draw too many beetles, with unexpected and perhaps disastrous consequences.

Antiaggregative pheromones are being developed to protect susceptible trees, stands, felled and bucked timber, and blowdown. Many of these pheromones have shown inconsistent results, but others are more consistent.

Verbenone

Verbenone is being extensively marketed—e.g., as BeetleBlock—to protect individual pine trees in home landscapes and other high-value situations and forest stands from mountain pine beetle attacks. Verbenone has shown promise when combined with extensive salvage and thinning treatments and at suboutbreak populations. During outbreaks, however, verbenone has been less effective. Recently, studies have indicated that protection was good when verbenone was aerially applied in plastic flakes; however, more study is needed.

Applying verbenone to protect pines from mountain pine beetle, although showing promise, has had mixed results and dictates a cautious approach to its use. Consult professional entomologists and technologists before using it on your property.

MCH

The antiaggregative pheromone MCH (3-methylcyclohex-2-en-1-one) has shown consistently good results in protecting down and/or standing, high-value Douglas-fir trees from Douglas-fir beetle, and it has had some success in spruce.

When to use MCH. MCH applications are appropriate when Douglas-fir beetle mortality is expected to significantly affect your long-term forestry management plan. The product can prevent population build-ups in windthrow, protect high-value individual trees, protect windthrow from being infested if it can't be salvaged before beetle flight, and protect at-risk Douglas-fir stands as large as 300 acres.

First, determine stand risk:

- Does the stand have significant amount of large, old Douglas-fir trees?

- Has the Douglas-fir beetle killed trees in the stand or adjacent stands in recent years?
- Has a disturbance, such as a windstorm, especially a larger event, occurred in the stand or in adjacent stands in the last 2 years?
- If the answer is yes to these questions, there is a good chance that Douglas-fir beetle populations are high and MCH may be an option to consider in protecting remaining trees.

How to use MCH. MCH is packaged in bubble caps, which are stapled to the shady side of trees, brush, or fence posts about 6 feet off the ground. Bubble caps can be deployed as early as January but no later than early April—in any case, before beetle flight in the spring.

Deploy them as follows:

- To treat areas larger than 2 acres, place bubble caps at roughly 15-foot intervals around the perimeter, then evenly distribute remaining capsules inside the unit. Target dosage is 30 bubble caps per acre.
- For areas 2 acres or smaller, place bubble caps around the perimeter at 15-foot intervals.
- For areas less than 0.5 acre, evenly space at least 16 capsules around the perimeter.
- On single trees, evenly space four bubble caps around the tree about 12 feet off the ground.

To protect blowdown and logs, only one treatment is needed. To protect stands or individual trees, retreat each year that Douglas-fir beetle infestation is likely.

Use pesticides safely!

- *Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.*
- *Read the pesticide label—even if you've used the pesticide before. Registrations may change or be withdrawn at any time. Follow closely the instructions on the label (and any other directions you have).*
- *Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.*

Important steps when using MCH include:

- Store bubble caps in a freezer, refrigerator, or cold room whenever possible.
- Avoid extensive exposure to bubble cap fumes during transport and application, and wear chemical-resistant gloves when handling.

- If people are often in the area, attach capsules high enough that people are unlikely to disturb them.
- If desired, remove bubble caps, but no earlier than September.
- Evaluate treatment 1 year after application.

When considering any pheromone strategy, consult entomologists and professionals with experience in this technology.

Synthetic insecticides

Certain formulations of carbaryl (e.g., Sevin SL and Sevin 4L) are registered for forest and landscape use to prevent bark beetle attacks on individual trees. Several other products are registered only for home landscape use: permethrin (Astro, Dragnet, and others) and bifenthrin (Onyx). Some products are designed for use only by licensed pest control operators and may not be available to homeowners. Consult the most current issue of the *Pacific Northwest Insect Management Handbook* for up-to-date pesticide recommendations (https://pnwhandbooks.org/insect). These sprays are applied to living green trees in spring or early summer, before beetle flight, to kill or deter attacking beetles.

For best results, saturate the bark all around the tree bole up to the point bole diameter narrows to 4 to 6 inches. (For the red turpentine beetle, treat the lower 8 feet of the bole.) Carbaryl can remain effective through two seasons. It's expensive, so you may wish to spray only the most valuable trees. During an epidemic, results may be less than satisfactory.

If treated trees die anyway, typically it's due to one or more of these reasons:

- The tree was incorrectly identified as healthy. Under dry conditions, for example, trees attacked by mountain pine beetles may not produce pitch tubes.
- The tree was not covered thoroughly. For example, the spray was not applied high enough on the trunk or didn't cover the entire trunk.
- The dosage was too low, or there were mixing problems.
- The material wore off or was washed off by rain soon after application.
- The material's effectiveness was compromised by improper storage conditions.

Biological controls

Bark beetles have a number of natural enemies that are important when beetles are at normal population levels. Woodpeckers and insects such as clerid beetles feed on larvae and adults under the bark. During outbreaks, however, these natural controls are overwhelmed and fail to keep beetle populations in check.

To encourage beetles' natural enemies:

- Retain snags as habitat for cavity-nesting birds, including woodpeckers which feed on bark beetle larvae. Desirable snag features include large diameters, hollow interiors, and stem decay.
- Maintain a diversity of tree and shrub species and a diverse stand structure to enhance habitat for insect predators and parasites.

Summary of management steps

Management scenario: Even- and uneven-aged systems

Management steps:

- Keep stand density below the self-thinning threshold.
- When thinning, retain trees with good, healthy crowns and crown ratios of at least 30 percent.
- When operating in the stand, be sure not to damage shallow surface roots or to wound leave trees (see Chapter 7).
- Match species to site conditions so trees are well adapted and grow well.
- Manage pine slash to prevent big jumps in *Ips* populations that kill nearby trees.
- For stands managed by single-tree selection, be sure to thin all age classes and to adjust spacing based on individual tree size (larger trees need more space than smaller trees).
- Increase landscape diversity by creating an array of stands of different age classes and stands with several age classes. Encouraging stands of multiple species also will improve forest resilience.
- Consider the full range of silvicultural options when managing bark beetles, such as clearcutting, shelterwood cutting, salvage and sanitation, and thinning. Your choice will depend on stand conditions, the bark beetle species, and your management objectives.
- Remember, each tree species is attacked by only a specific bark beetle or a small group of bark beetles. Also, a particular bark beetle species prefers certain tree sizes or locations on the tree bole; for example, Douglas-fir beetle prefers tree DBH greater than 14 inches except in southwest Oregon, where it prefers DBH greater than 10 inches.
- To protect individual high-value trees, such as trees around the

home or in recreational areas, apply a protective spray such as carbaryl.

- When ambrosia beetles are flying, move logs from woods to mill soon after cutting.
- MCH, a registered pheromone used to protect Douglas-fir logs and trees from Douglas-fir beetle attack, is a viable option. MCH also can be effective for spruce beetle. Studies of verbenone effectiveness on mountain pine beetle show mixed results.

Management scenario: Fire

Management steps:

- After a fire, assess the trees' potential for survival by using available after-the-fire guides.
- Remove fire-killed and high-risk trees within 1 year after the fire.

Management scenario: Blowdown

Management steps:

- Remove down trees within 1 year after blowdown to prevent bark beetles, such as Douglas-fir beetle and spruce beetle, from developing large broods in the blowdown and thus threatening nearby stands.
- If salvage will be delayed longer than 1 year, an option is to apply MCH before beetle flight, to prevent beetle attacks on the log.
- Remove pine blowdown by June, to minimize damage from Ips.

Management scenario: Root disease and dwarf mistletoe

Management steps:

- Follow recommendations to decrease disease problems and improve tree vigor on the site.

Management scenario: Wildlife enhancement

Management steps:

- Leave two or three bark-beetle-killed trees per acre to provide snags for cavity-nesting birds and mammals. Snags eventually will become down logs—habitat for different wildlife—and a source of nutrients for recycling.

Photo: Peg Herring, © Oregon State University

A stand of mixed ponderosa pine and Douglas-fir in the Blue Mountains of Oregon.

CHAPTER 3

Defoliating Insects[4]

The immature, or larval, stages of moths, butterflies, and sawflies are the most important defoliating insects on conifers. These chewing insects feed on needles from the outside, mine inside them, or sever them from the branch. From a distance, chewing damage may look as if the tree has been singed by fire.

Typically, defoliator populations are cyclic. Outbreak duration and intervals vary greatly, depending on the defoliator species, weather, and other factors. Many defoliating insects prefer either current- or previous-year foliage. This affects the defoliation pattern on the tree, which helps to identify the pest.

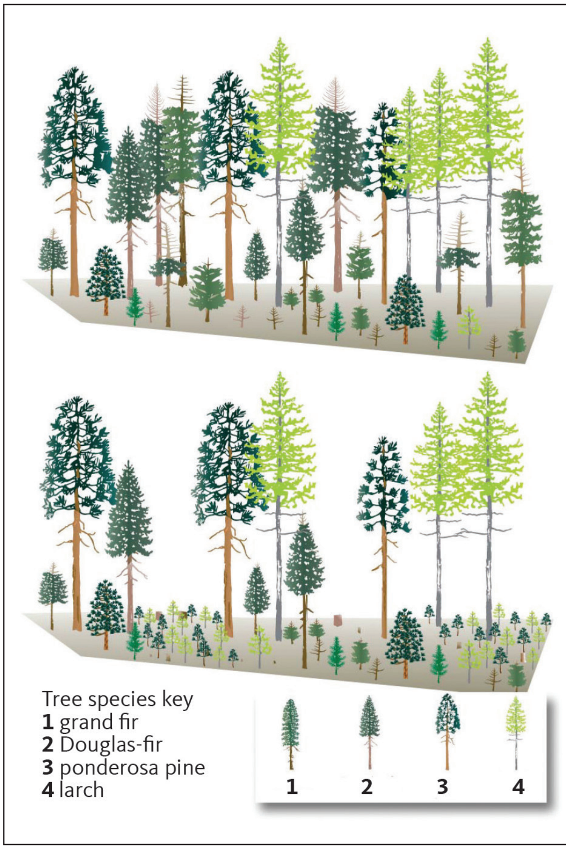

Illustration: Gretchen Bracher

Figure 3-1. To lower stand risk of attack by Douglas-fir tussock moth and western spruce budworm, shift tree species away from susceptible hosts.

Insect defoliators can retard growth or kill tree tops or the entire tree, depending on how much foliage is lost, the host species' tolerance to defoliation, and how many years trees are defoliated. Defoliation also weakens trees, making them more susceptible to bark beetle attacks. Table 3-1 (pages 40–42) gives an overview of Oregon's more important defoliators.

[4] Goheen & Willhite, 228–271

Management strategies for specific pests

Douglas-fir tussock moth

This insect is an important pest of Douglas-fir and true firs east of the Cascade crest. Larvae feed first on new foliage, then switch to older foliage as new foliage becomes limited. The insect has a 1-year life cycle, and outbreaks are relatively short, about 3 to 4 years. A naturally occurring virus that kills larvae triggers the collapse of an outbreak.

Stands on warm, dry, upper sites where soils are shallow, such as ridgetops, are more susceptible than trees on cooler, moister sites. Often, these stands have developed as a result of long-term fire suppression and selective logging that removed much of the ponderosa pine. Converting these stands to early seral species such as ponderosa pine (on drier sites) or larch (on wetter sites) or converting to little-damaged hosts such as incense-cedar will reduce Douglas-fir tussock moth risk (Figure 3-1, page 35).

Management strategies

Silvicultural techniques. Young larvae tend to survive better in multistoried stands of host trees (Figure 3-2). Simplifying stand structure to one or two age classes helps reduce damage. Well-spaced, healthy stands suffer the least damage. In mixed-conifer forests, maintain or shift the proportion of Douglas-fir and true fir to 30 percent or less.

Do not thin affected pure-host stands during or immediately after an outbreak. It's difficult to predict which trees will recover from defoliation and which will escape bark beetle attacks. After a heavy thinning in dense stands, shade-tolerant leave trees may go into shock because their needles can't adapt to the extra sunlight fast enough, which will further weaken the trees. However, thinning mixed-species stands to remove damaged host trees and favor nonhosts should work well.

Population surveys. Pheromone-baited traps can help you survey Douglas-fir tussock moth populations, detect increases early, and organize large-scale control strategies. The Early Warning System (EWS) pheromone trap network provides a 1- to 3-year warning of potential outbreaks, allowing managers time to develop effective responses. For current EWS information on the status of Douglas-fir tussock moth population levels, visit https://www.fs.usda.gov/main/r6/forest-grasslandhealth/

Chemical and biological controls. Quickly suppressing an outbreak in its early stages can save stands from defoliation. Once the population has peaked, however, spray programs are unnecessary and not cost-effective because the naturally occurring virus may initiate population collapse.

Aerial application of contact insecticides (e.g., carbaryl), the naturally occurring bacterium *Bacillus thuringiensis* var. *kurstaki* (Btk), and the nucleopolyhedrosis virus have suppressed tussock moth populations. Btk targets only Lepidoptera larvae that feed on treated foliage. Btk applications require more careful timing than applying contact insecticides and must be managed carefully to assure effective coverage.

Applying the virus, which is specific to Douglas-fir tussock moth, may be an option for woodland owners cooperating with federal suppression projects. Currently, the Forest Service maintains a supply of the virus and uses it to some degree on federal lands; however, it is not available commercially.

Trained professionals should advise on any aerial spraying. Individual high-value trees (including genetically superior seed trees) can be

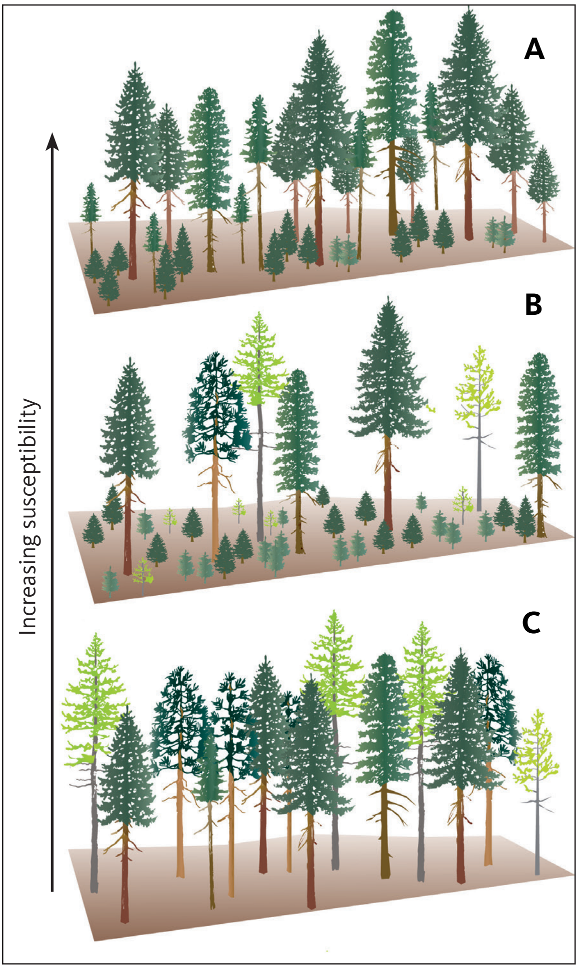

Illustration: Gretchen Bracher

Figure 3-2. As stand structure becomes more layered with host species, the risk of defoliation increases. In this example, an uneven-aged Douglas-fir and grand fir stand (A) is most susceptible, while a mixed stand (C) of pine, larch, and some Douglas-fir—which is relatively even-aged and well spaced—is least susceptible to insect impacts.

protected by implanting systemic insecticides such as ACECAP Systemic Insecticide Implants (acephate is the active ingredient) in the trunk in fall or early spring at 4-inch intervals around the tree trunk. Consult the most current issue of the *Pacific Northwest Insect Management Handbook* for up-to-date pesticide recommendations (https://pnwhandbooks.org/insect).

Chemical control may be an option if your stand of highly susceptible trees is very near harvest. Although chemical control can save trees, it should be considered as only a short-term solution. Douglas-fir tussock moth outbreaks are cyclic. Without lowering high-risk factors in the stand, such as multilayering and a high proportion of fir, stands will be highly susceptible to damage the next time populations increase. The best long-term solution is to follow the silvicultural guidelines described above.

Western spruce budworm

This insect prefers new foliage, and early spring feeding can include buds and newly developing cones. Repeated, heavy feeding on current-year foliage can retard growth and kill the tree top; after 4 to 5 years of repeated defoliation, the tree may die. Besides feeding on foliage, budworm larvae feed heavily on staminate flowers and developing cones. During outbreaks, expect little seed from host trees. Outbreaks are cyclic and can last up to 20 years but typically are about 10 years long.

The Modoc budworm (*Choristoneura retiniana*), a closely related species, is found in true firs and Douglas-fir forests of southern Oregon. The adults are smaller and a lighter color than the western spruce budworm, and mature larvae and pupae are green rather than brown. Management treatments for Modoc budworm are similar to those for western spruce budworm.

Management strategies

Silvicultural techniques. To improve forest resistance and resiliency over the long term, you must alter stand conditions. Most mixed-conifer forests of eastern Oregon are multilayered, overstocked, and dominated by Douglas-fir and true fir—prime fodder for budworms—because of aggressive wildfire control and logging that removed much of the ponderosa pine and larch. Tree-ring analysis dating back to the 1700s suggests that outbreak frequencies have increased in the last 100 years or so.

To lower the risk of budworm damage, reduce stand densities and canopy layering (Figure 3-1, page 35, and Figure 3-2, page 37) and diversify species. Focus your silvicultural treatments on thinning from below, making regeneration harvests, planting pines and larch and favoring those species in thinnings where they grow naturally, and using prescribed fire where appropriate.

Specific management steps include:

- Convert dry, fir-dominated stands to ponderosa pine, especially on lower-elevation or more droughty sites.
- Convert cool, moist sites to pines and larch.
- Manage stand densities at moderate stocking levels to benefit predators and parasites and to promote good tree growth and vigor.
- Reduce the proportion of host trees in mixed-species stands to 30 percent or less (Figure 3-1, page 35).
- In thinning, retain healthy trees with live-crown ratios of 30 percent or greater.
- Promote Douglas-fir over true firs on sites where they grow together.
- Use even-aged silvicultural methods (clearcut, seed tree, or shelterwood harvest systems and thinning from below) to create simple stand structures; i.e., one or two canopy layers (Figure 3-2, page 37).

If you are considering uneven-aged management, be aware that single-tree selection management on mixed-conifer sites tends to foster multistoried stands, which have shade-tolerant, budworm-susceptible understory species. Stands with host trees in multiple age classes are prone to greater damage because larvae move downward through the canopy, and the smaller trees end up with high concentrations of insects and thus greater damage. Group selection (harvest cuts of 2 to 4 acres) provides more opportunity to control species composition than single-tree selection. Uneven-aged, more open stands of ponderosa pine with some Douglas-fir should be relatively resistant to budworm.

Thinning, in itself, is not likely to reduce a host-dominated stand's susceptibility to defoliation from budworm, Douglas-fir tussock moth, or sawflies. However, trees in thinned stands recover from defoliation more rapidly than trees in unthinned stands.

Thinning that encourages a mixture of species will help reduce the effects of defoliation. Changing species composition to favor resistant species, changing stand structure, or both, will create less susceptible stands. For example, reducing density of true firs and Douglas-fir in the understory of mixed pine and fir stands makes it less likely that dispersing larvae find a host before they land on the forest floor and are killed by predators.

Table 3-1. Important defoliator species in Oregon: Hosts, key identifiers, distribution, and severity.

Defoliator	Major hosts	Key identifiers	Distribution and severity
Douglas-fir tussock moth *Orgyia pseudotsugata*	Douglas-fir and true firs	▪ "Top down" defoliation pattern ▪ Messily chewed, discolored foliage ▪ Hairy larvae ▪ Silken "caps" on tree tops ▪ Older foliage preferred	Outbreaks east of Cascade crest
Larch casebearer *Coleophora laricella*	Western larch	▪ Yellow to red foliage in spring ▪ Young larvae feed inside needles; older larvae and pupae are on the outside, in tube-like or cigar-shaped shelters ▪ Upper crown more severely affected	Throughout the range of western larch Damage rarely causes tree mortality. Introduced parasitoid wasps aid control of this non-native insect.

Continued on next page

Table 3-1. (continued) Important defoliator species in Oregon: Hosts, key identifiers, distribution, and severity.

Defoliator	Major hosts	Key identifiers	Distribution and severity
Pandora moth *Coloradia pandora*	Ponderosa pine, lodgepole pine, and Jeffrey pine	▪ Older foliage discolored and damaged ▪ Thinning tree crowns in late winter and spring at 2-year intervals through outbreak ▪ Caterpillars large, with brown and yellow bands, branched spines	Probably throughout the range of its hosts in Oregon; however, damaging outbreaks to date have been closely tied to areas with very loose soils, such as south-central Oregon pumice.
Pine butterfly *Neophasia menapia*	Ponderosa pine	▪ Older foliage preferred ▪ Thin tree crowns with foliage mainly at the branch tips ▪ Green caterpillars with two white, lateral stripes	In ponderosa pine known for rare, but spectacular, outbreaks, e.g., recent outbreak on the Malheur National Forest defoliated 250,000 acres. Other times, there may be a population increase where the defoliation is not noticed, but the abundance of butterflies is striking.
Sawflies, both free-feeding and web-spinning species *Neodiprion* spp., *Pristiphora* spp., *Acantholyda* spp., and *Cephalcia* spp.	Varies according to sawfly species; most conifers affected	▪ Generally, older foliage affected ▪ With or without webbing ▪ Foliage discolored ▪ Needle stubs	Throughout Oregon Outbreaks typically short lived, with little or no tree mortality.

Continued on next page

Table 3-1. (continued) Important defoliator species in Oregon: Hosts, key identifiers, distribution, and severity.

Defoliator	Major hosts	Key identifiers	Distribution and severity
Silver-spotted tiger moth *Lophocampa argentata*	Douglas-fir	▪ Dense colonies of overwintering larvae on twigs ▪ Larval feeding through winter when temperatures are favorable ▪ Appearance and dispersal of large, hairy caterpillars early in spring ▪ Loose webs with accumulated dead needles and frass ▪ Whole branches stripped, mostly in upper crown	Western Oregon, especially in coastal forests Not considered a major pest; natural enemies usually keep populations under control.
Western spruce budworm *Choristoneura freemani*	Douglas-fir and true firs	▪ Current-year foliage chewed, with or without webbing, and discolored ▪ Defoliation worst in tops and on small trees ▪ Mature larvae 1 inch long and brown with ivory spots	Most of Oregon, but impacts greater east of Cascade crest Outbreaks in Douglas-fir and grand fir east of the crest can persist for many years and cause significant growth impacts as well as top dieback and tree mortality.

Chemical and biological controls. Contact insecticides and Btk have been applied by air to reduce budworm populations and tree damage, but use them only in limited, appropriate situations, such as protecting high-value, high-risk true fir stands. Usually it's necessary to repeat applications for the duration of the outbreak. Because outbreaks are cyclic, pesticide treatments are a short-term solution. For long-term protection, use silvicultural approaches outlined above.

Trained professionals should advise on any aerial spraying. Individual high-value trees (including genetically superior seed trees) can be protected by implanting systemic insecticides, such as ACECAP Systemic Insecticide Implants (acephate is the active ingredient), in the trunk in fall or early spring at 4-inch intervals around the tree trunk. Consult the most current issue of the *Pacific Northwest Insect Management Handbook* for up-to-date pesticide recommendations (https://pnwhandbooks.org/insect).

> ***Use pesticides safely!***
>
> - *Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.*
> - *Read the pesticide label—even if you've used the pesticide before. Registrations may change or be withdrawn at any time. Follow closely the instructions on the label (and any other directions you have).*
> - *Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.*

Natural predators and parasites are important regulators of budworm populations and are thought to delay or reduce the frequency of outbreaks. Promote good predator and parasite populations with these practices:

- Provide habitat for birds and ants by allowing for shrubs, a mixture of tree species, large down logs (at least 12 inches in diameter and 16 feet long), and snags (at least 12 inches in diameter and 20 feet high).
- Protect ant colonies, especially carpenter ants, during harvest. Identify ant nests before operations begin, then manage felling and skidding to minimize disturbance.

Larch casebearer

This small moth was introduced from Europe in 1886. Since, it has spread across the range of western larch and is now its most serious insect pest. Young larvae cause defoliation by mining inside needles and then feeding more voraciously on new growth while still inside their needle "homes." Identify this insect by its small, cigar-shaped case on a branch.

Larch casebearer has a 1-year life cycle. Larch usually can withstand repeated light to moderate defoliation because it can produce more needles late in the growing season. However, continued heavy defoliation for 5 years or more can retard growth, cause branch dieback, and occasionally may stress a tree, especially a smaller one, enough that it succumbs to other factors.

Management strategies

Silvicultural techniques. Little is known about how actions such as thinning affect larch casebearer populations and damage or predator and parasite relationships. Stress factors that weaken trees, such as dwarf mistletoe, probably add to decline in defoliated trees. Promoting vigorous growth should allow better recovery once defoliation subsides. Until we know more, manage stands with larch at moderate stocking levels, promote mixed-species compositions, and, in thinning, leave disease-free trees with long, dominant crowns.

Biological control. A number of native predators, including birds and arthropods, and parasites feed on larch casebearer but don't appear to control growing populations. Two European parositoid wasps, *Agathis pumila* and *Chrysocharis laricinellae*, were introduced into North American larch stands in the early 1960s. Early monitoring of these biological control agents was promising: the two wasps appeared to increase their populations in tandem with increasing larch casebearer populations. Recent monitoring shows that both parasitoid wasps are well established in Oregon as well as throughout the range of western larch. These parasites—along with environmental factors that help regulate populations, such as cold, wet springs with frosts—will lessen larch casebearer defoliation and future outbreaks.

Hypodermella laricis, which causes a needle blight, and *Meria laricis*, which causes a needle cast (see Chapter 8, page 93), limit foliage available to the casebearer and so appear to help moderate casebearer outbreaks. Symptoms of these needle diseases can be confused with casebearer defoliation; however, the needle diseases normally are concentrated in the lower crown, while casebearer damage typically is in the upper crown or throughout the crown.

Chemical control. No pesticide is registered for treating larch casebearer in Oregon. Besides, aerial pesticide application isn't practical because larch is scattered across the landscape in mixtures with other species.

Long-term strategy. Given larch's ability to refoliate late in the growing season, and the existence to some degree of predator and parasite controls, the long-term management strategy for this pest is to let natural processes take effect.

Pandora moth

This moth has had spectacular outbreaks in central Oregon ponderosa pine forests, especially in areas with loose soil structure. The insect has a 2-year life cycle; outbreaks typically last three to five generations (6 to 10 years). Population declines are tied to the build-up of a naturally occurring virus.

Larvae feed on older foliage. Severe defoliation typically is spotty, and severely defoliated trees have reduced vigor and diameter growth. Trees seldom die from pandora moth defoliation because larvae don't eat new growth and because most defoliation is in alternate years, allowing trees to recover. Heavily defoliated trees are weakened and may sometimes be at risk from bark beetles. Trees are more likely to die if defoliation combines with other stress factors, such as dwarf mistletoe, drought, competition with other trees, and physical damage.

Management strategies

Silvicultural techniques. In lightly defoliated stands, special treatment probably is not necessary. In stands with heavy defoliation, consider thinning, but wait until the outbreak is over and you can see which trees regrow their needles and are likely to survive. Leave the most vigorous, deeply crowned trees, and space trees according to guidelines. Treatments that maintain desirable stocking and reduce the incidence of dwarf mistletoe can minimize growth losses from defoliation.

Prescribed fire in late June or July can reduce the population of overwintering pupae in soil. However, landowners generally are reluctant to use fire because of liability concerns, lack of proper equipment and labor, and limited knowledge of best techniques. Consider this option only after careful consultation with fire specialists and entomologists familiar with the moth's local life cycle.

Chemical control. No insecticide is registered for control of pandora moth in Oregon for forest stands, and usually none is necessary. Homeowners can keep trees vigorously growing by fertilizing and thinning. If insecticides are used in landscape plantings, for maximum effectiveness apply them in September and October, when caterpillars are small. Spraying in spring is an option, but because larvae are larger, control may be limited. Consult the most current issue of the *Pacific*

Northwest Insect Management Handbook for up-to-date pesticide recommendations (https://pnwhandbooks.org/insect).

Pine butterfly

A common Oregon butterfly, the pine butterfly can erupt in large populations that fly in spectacular fashion during mid to late summer. In ponderosa pine, the butterfly caterpillars can defoliate large regions. Outbreaks last only a few years and the caterpillars prefer older foliage, but they consume new foliage if the outbreak persists. Predators and parasitoid wasps appear to control the butterfly populations after they become abundant.

A recent outbreak on the Malheur National Forest was estimated to cover 250,000 acres. Trees were defoliated regardless of size, canopy position, density, or even- versus uneven-structured stands.

Management strategies

Unlike its effect on Douglas-fir tussock moth and western spruce budworm, controlling stand structure does not appear to influence defoliator patterns. We recommend standard silviculture of ponderosa pine that maintains tree vigor so that defoliated trees can tolerate and recover from the defoliation.

Sawflies

Native sawfly outbreaks are sporadic, occur at long intervals, and generally are short, lasting 1 or 2 years. Most outbreaks collapse with little or no tree mortality unless the insect is feeding with other defoliators, particularly the black-headed budworm. Since the budworm prefers new foliage and the sawfly prefers older foliage, their combined feeding may completely defoliate trees. Heavy defoliation during an outbreak can kill some trees and reduce the growth and vigor of others, thus subjecting them to attack by other insects. The majority of damage occurs in urban landscapes where off-site trees, such as non-native pines, have been planted.

Management strategies

Adverse, cold weather, a naturally occurring fungus and virus, and native parasites are known to control sawflies. Management rarely is necessary.

Silver-spotted tiger moth

A native insect, this moth is the most common defoliator of conifers in western Oregon. Outbreaks are typically short, and damage is spotty both in the tree and across the landscape. Although the damage can look dramatic and cause concern, natural enemies, especially parasitization by tachinid flies, keep populations in check, and damage normally lasts only 1 or 2 years.

Management strategies

Generally, no management treatments are necessary in forest stands. Ornamental trees can be treated with insecticides. An alternative is to remove and destroy affected branches. Consult the most current issue of the *Pacific Northwest Insect Management Handbook* for up-to-date pesticide recommendations (https://pnwhandbooks.org/insect).

Photo: U.S. Forest Service

Balsam woolly adelgid damage to a subalpine fir stand.

Chapter 4

Aphids, Adelgids, and Scale Insects[5]

Sucking defoliators—including aphids, adelgids, and scale insects—insert their straw-like mouth parts into foliage and stem tissue and draw out plant juices. Defoliation results when affected needles deteriorate and fall off. Symptoms can appear as stippled foliage (dead spots), needle necrosis, needle distortion such as twisting or stunting, and a thinning crown (Table 4-1, page 54).

Management strategies for specific pests

Balsam woolly adelgid

Balsam woolly adelgid (BWA) originated in Europe and first appeared in Oregon in the 1920s. It attacks true fir species, principally grand fir at lower elevations in western Oregon, subalpine fir, and Pacific silver fir. It can also be found on off-site plantings of noble and white fir.

Although widespread tree mortality subsided after outbreaks in the 1950s and '60s, this insect currently is in resurgence and is causing significant mortality of subalpine fir at high elevations. It has greatly reduced grand fir at low elevations in the Willamette Valley and, in some high-elevation areas, has eliminated subalpine fir and damaged other true firs.

Susceptibility of Pacific silver fir to BWA appears to increase at elevations below 3,000 feet in the Coast Range and Cascades; stands most heavily damaged are on the wettest sites at lower elevations. However, damage is variable throughout the range of Pacific silver fir, which makes forest managers reluctant to plant it. A new method of assessing the impacts of BWA involves evaluating the overstory and understory of true firs for dieback, crown deformity, branch gouting, and tree mortality (Figure 4-1).

Photo: Dave Shaw, © Oregon State University

Figure 4-1. Balsam woolly adelgid can cause these swollen areas, or "gout," at internodes of branches on its host. The gouting amount is used to evaluate insect severity.

All BWA individuals in North America are females capable of

[5] Goheen & Willhite, 140–141 and 272–285

reproducing without males. Thus, once established, BWA tends to persist indefinitely on a site.

Management strategies

BWA has no known native predators or parasites. Significant numbers of predators from Europe, Asia, and Australia have been introduced as biological control agents. A recent review found six beetle and fly species had become established; however, none appeared to be having an impact on BWA populations.

Cold winters are thought to reduce BWA survival, but populations often recover quickly and continue to cause damage.

Management steps on forest sites (Figure 4-2, page 52) include:

- Harvest the infested and at-risk true firs and plant nonhost trees adapted to the site.
- Thin out damaged true firs in infested, mixed-species stands.
- On infested sites, collect true fir cones from trees without symptoms.
- Plant site-adapted species
- Management steps with ornamental trees include:
- Replace the infested tree with a nonhost tree.
- Do not apply nitrogen fertilizer (e.g., urea) to infested trees; it may enhance adelgid survival and reproduction.
- If using an insecticide (e.g., carbaryl) good coverage is essential, and the application must be carefully timed to coincide with the BWA crawler stage, when the insect is most vulnerable. Usually this stage is at or near budbreak in early spring, but timing varies with annual weather patterns. A generally better approach for sap-feeding insects in landscape settings is to use a systemic, such as imidacloprid, that can be applied to soil or injected into the stem. Consult the most current issue of the *Pacific Northwest Insect Management Handbook* for up-to-date pesticide recommendations (https://pnwhandbooks.org/insect).

Spruce aphid

Sitka spruce trees with sparse crowns, caused by losing older needles, are likely victims of the spruce aphid. Much of the Sitka spruce decline along the Oregon coast is due in large part to spruce aphid. The insect can affect native and ornamental spruce and lives in both western and eastern Oregon, although eastern Oregon populations develop later in the spring. Large trees tend to be severely defoliated.

Weather and other natural factors normally control aphid populations before they cause significant damage. Mild winters tend to favor population expansions. Prolonged cool temperatures or early spring frosts can help to lower populations.

Management strategies

Fertilizing spruce with nitrogen is not recommended because of increased foliage flushing and because an increase of nitrogen in foliage may favor higher aphid populations. Other nutrients may help or be neutral.

No insecticides for spruce aphid are registered for forest trees. Lower populations on smaller, high-value trees around homes or in parks can be treated with contact pesticides, including insecticidal oils and soaps, and synthetic insecticides. Early season timing (before needle drop) and thorough coverage are essential for success. Better choices for larger trees are trunk or soil applications of systemic insecticides such as acephate or imidacloprid. Consult the most current issue of the *Pacific Northwest Insect Management Handbook* for up-to-date pesticide recommendations (https://pnwhandbooks.org/insect).

Black pineleaf scale

The black pineleaf scale (BPS) is one of the more important scale insects because it has caused visible damage and some mortality in pine forests in local areas of eastern Oregon, especially near commercial agriculture areas or where mosquitoes are sprayed, as well as in low-elevation, poor growing areas.

BPS, along with other scale insects such as pine leaf scale, can be a problem along dusty roads or in landscape plantings. High scale populations lower tree vigor and increase tree susceptibility to bark beetles.

Natural factors help regulate BPS populations. Several species of parasitic wasps and predatory beetles can control the insect. Weather also plays a role; in particular, prolonged cold and rapid temperature drops during spring development can reduce BPS survival.

Moisture stress affects trees' susceptibility and resiliency to infestations. Stands on the fringe of rangeland (i.e., marginally productive forest sites), upland sites, south slopes, or sites that are overstocked or experiencing extended drought are at higher risk. Pole-size and larger trees are at greater risk of attack and defoliation.

Management strategies

Biological control. In stands exposed to insecticide spray drift, large BPS populations can build up because the spray impacts the insects' natural predators and parasites, including behavioral changes. Because scales are protected by their shells, they are not affected by heavy dust on foliage along roads—but their predators and parasites are affected.

To protect natural predators:

- Apply insecticides to crops when temperature, relative humidity, and wind direction and velocity are within the prescription window. This allows the insecticide to settle on the target plants instead of drifting off site.
- Avoid using mosquito fogging in areas or near home sites with mature pines.
- Control dust along roads, construction sites, and urban and industrial areas to increase predator and parasite populations.

Silvicultural techniques. Silvicultural practices that can help tree resistance include thinning and, in home landscapes, watering. Watering improves tree crowns and so increases the tree's tolerance to scale infestation.

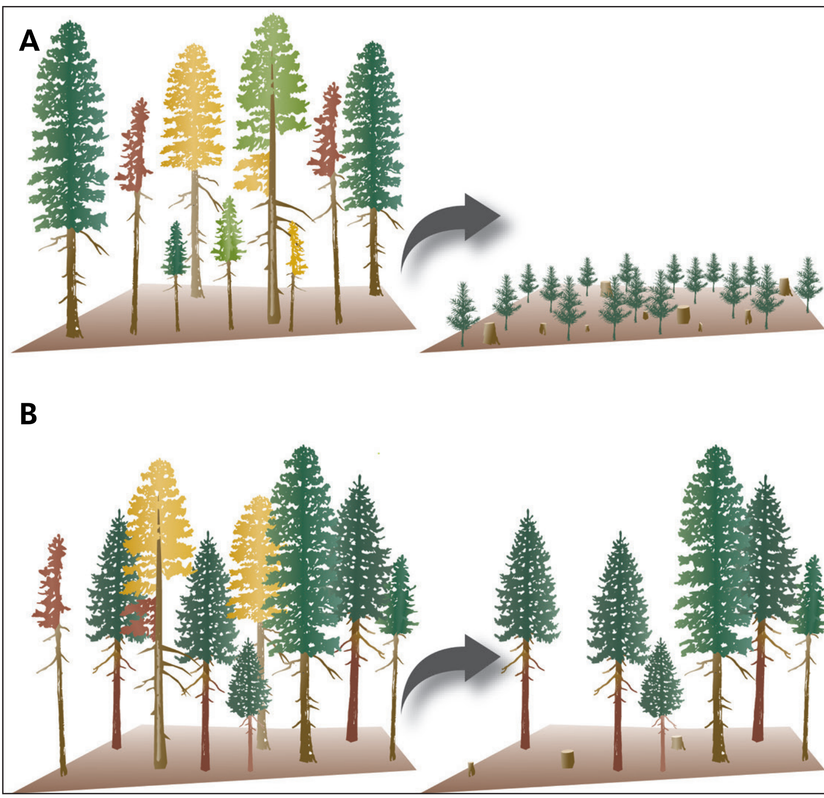

Illustration: Gretchen Bracher

Figure 4-2. Balsam woolly adelgid management: (A) In infested stands dominated by true fir, harvest damaged and high-risk species and convert to nonhost species that are adapted to the site. (B) In mixed-species stands, remove damaged and high-risk hosts.

Thinning reduces competition for moisture and thus fosters tree vigor. Choosing leave trees with live-crown ratios of at least 30 percent is essential to keeping vigor high in your stand. Thinning also can help control the insects' spread. Wind can carry BPS crawlers, so thinning dense stands improves the chance that windblown crawlers will fall to the ground and starve or become prey.

Infestation severity assessment. The severity of an infestation indicates whether management intervention is needed. To assess severity, count the number of live scale insects per inch of needle on current-year growth. The sampling process outlined here may be more intensive than some forestland owners will want to do themselves; however, understanding the process will be helpful even if the work is contracted.

To assess an individual tree, take four branch samples from the lower to middle crown (one branch from each side of the tree), then randomly sample at least 25 needles of current-year growth per branch (100 needles per tree). For stands, use a systematic tree-selection approach that covers the area, selecting a total of at least 10 dominant or codominant trees.

Count the number of scale insects per inch of needle. If the average insect count is less than half a scale per inch, damage is not likely. Densities of up to four scales per inch of needle could reduce growth, but detailed studies are lacking. Densities greater than four scales per inch of needle have been shown to reduce needle length and retention. If this continues over several consecutive years, it can lead to reduced twig or leader lengths and a decline in radial growth. At densities above 20 insects per inch (over several years), needle loss can be severe and, along with additional declines in terminal and radial growth, can make trees more susceptible to being killed by bark beetles or other agents, such as drought.

Chemical control. Foliar sprays of contact insecticides are generally not recommended; they are difficult to time correctly (must be when crawlers are moving onto new needles) and may also harm natural enemies. Systemic insecticides (acephate or imidacloprid) injected into the trunk or soil in early spring can also be used to reduce populations on high-value trees. However, scale populations may continue to rise unless the underlying causes are resolved, such as poor site conditions, spray drift, and dust. Consult the most current issue of the *Pacific Northwest Insect Management Handbook* for up-to-date pesticide recommendations (https://pnwhandbooks.org/insect).

Table 4-1. Important sucking defoliators in Oregon: Hosts, key identifiers, distribution, and severity.

Pest	Major hosts	Key identifiers	Distribution and severity
Balsam woolly adelgid (introduced) *Adelges piceae*	True firs, especially grand fir, Pacific silver fir, and subalpine fir	▪ White "woolly" tufts on tree branches and boles ▪ Swollen (gouty) branch nodes and terminal buds ▪ Misshaped crowns ▪ Thin, reddish brown or blackish green crowns	Throughout Oregon Particularly susceptible are grand fir in western Oregon lowland valleys and Pacific silver fir and subalpine fir at the lower extremes of their ranges.
Spruce aphid (introduced) *Elatobium abietinum*	Sitka spruce and ornamental spruces	▪ Chlorotic (yellowing) or sparse foliage ▪ Healthy green branch tips ▪ Small green aphids on underside of older needles	Coastal Oregon on Sitka spruce; throughout Oregon on ornamentals Outbreaks on Sitka spruce are sporadic and short lived.
Black pineleaf scale *Nuculaspis californica*	Ponderosa pine, sugar pine, Jeffrey pine, and lodgepole pine	▪ Small, black scale insects on needles ▪ Thin tree crowns ▪ Foliage mostly at branch tips ▪ Discolored and stunted needles	Throughout Oregon, but most damage is east of the Cascade crest. In local areas, damage can be significant; infestation predisposes trees to bark beetle attack.
Pine needle scale *Chionaspis pinifoliae*	Ponderosa pine and lodgepole pine	▪ White scale insects on needles	Throughout host range. Weakened trees are susceptible to bark beetle attack and slower growth.

Chapter 5

Terminal and Branch Insects and Pitch Moths[6]

Terminal- and branch-feeding insects are most common on young trees. The most important groups in Oregon include beetles, weevils, and moth larvae (Table 5-1, page 57). Life cycles generally are completed in 1 year.

Damage appears as stunted or dead tops and dead branches. Damage to terminal leaders reduces height and volume growth, crooks or forks the tree tops, and deforms the trees.

Pitch moths can damage trees of all ages and, if attacks are severe enough, they can reduce tree vigor.

Management strategies for specific pests

Western pine shoot borer

Damage from this insect is most severe in eastern and southwest Oregon. On a given site, pines with good growth rates are more likely to be attacked than trees growing more slowly; therefore, intensive site preparation, including controls on competing vegetation, can increase infestation levels. Observations are that ponderosa pine on poorer sites may suffer a higher level of infestation, and higher-elevation plantations tend to have less damage.

Once trees reach 3 to 4 feet in height, they become susceptible to tip damage. Susceptibility to growth reductions and deformed tops is greatest when height reaches 4 to 10 feet. After 25 to 30 years, attacks are less frequent, and damage is not as severe.

Attacked terminal shoots usually don't die, but growth reductions of 25 percent are associated with each individual attack. Reduced terminal shoot growth also causes shorter internodes, so lumber from infested trees will have more knots. When the terminal shoot dies, tree form can be affected; this lowers the growth and value of infested trees and causes multiple-top trees.

Management strategies

Silvicultural techniques. Growing ponderosa pine in an understory (e.g., in uneven-aged management) may reduce damage; however, the trade-off is slower growth of understory pines. Shade-induced growth reductions must be weighed against the growth reduction that western pine shoot borer might cause.

[6] Goheen & Willhite, 146–147 and 176–190

Using treatments that accelerate tree growth—such as good site preparation, weed control, and thinning—can reduce the time trees are in the most susceptible phase; however, as already noted, fast-growing trees also can be more vulnerable to attacks (see Figure 5-1, option 1).

Another strategy is to delay thinning for 20 to 25 years, then take out affected trees with a late precommercial thinning. The disadvantage to this is that delaying thinning increases the time to the first commercial thinning (see Figure 5-1, option 2).

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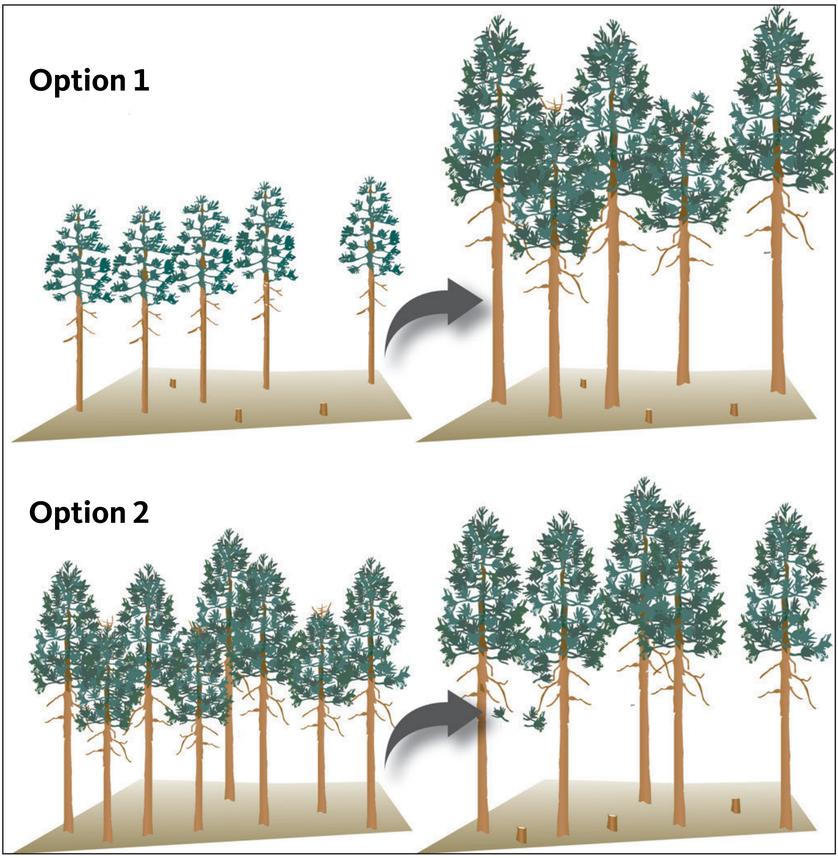

Illustration: Gretchen Bracher

Figure 5-1. Western pine shoot borer silvicultural management control strategies. Option 1: Thin early to accelerate tree growth so trees quickly pass the susceptible height. The tradeoff is damaged tops on some trees, which reduces their height growth and causes some deformed or multiple tops. Option 2: Delay thinning for 20–25 years after stand establishes. A late thinning removes damaged trees; however, some growth will be sacrificed because of the delayed thinning.

Table 5-1. Most common terminal and branch forest insect pests in Oregon: Hosts, key identifiers, and distribution.

Insect	Major hosts	Key identifiers	Distribution
Douglas-fir twig weevil *Cylindrocopturus furnissi*	Douglas-fir	▪ Dead twigs (flagging) on young, open-grown trees ▪ Bark irregularities ▪ Mined pith ▪ Frass and feeding galleries under twig bark ▪ Exit holes	Throughout host range, particularly on low-elevation, stressful sites.
Douglas-fir pitch moth *Synanthedon novaroensis*	Douglas-fir, spruce, ponderosa pine, western white pine, lodgepole pine, larch	▪ Large masses of clear, yellowish, or grayish pitch on the bole, especially near limb junctions or injuries ▪ Whitish caterpillar under pitch mass	Throughout host range.
Gouty pitch midge *Cecidomyia piniinopsis*	Ponderosa pine	▪ Current-year shoots twisted, stunted, and/or dead ▪ Associated concentrations of pitch ▪ Severely distorted trees, usually trees 4–16 feet tall, after repeated attacks	Throughout Oregon, especially southwest.
Lodgepole terminal weevil *Pissodes terminalis*	Lodgepole pine	▪ Discolored, drooping, or dead terminal leader ▪ Mining under bark and in pith of infected leader ▪ Legless larvae or chip cocoons under bark of leader	Throughout host range.

Continued on next page

Table 5-1. (Continued) Most common terminal and branch forest insect pests in Oregon: Hosts, key identifiers, and distribution.

Insect	Major hosts	Keyidentifiers	Distribution
Sequoia pitch moth *Synanthedon sequoiae*	Most pine species and Douglas-fir	▪ Large masses of clear, yellowish, or grayish pitch on the bole, especially near limb junctions or injuries ▪ Whitish caterpillar under pitch mass	Throughout host range.
Western pine shoot borer *Eucosma sonomana*	Ponderosa pine, lodgepole pine, knobcone pine, and Jeffrey pine	▪ Stunted, green terminal leaders with a “shaving brush” (short needles) look ▪ Mined pith packed with dark frass ▪ Dead lateral branch tips	In eastern and southwest Oregon.
White pine weevil (Sitka spruce weevil) *Pissodes strobi*	In Oregon, Sitka spruce and Engelmann spruce	▪ Discolored, drooping “shepherd’s crook” terminal leader ▪ Larval mining under bark ▪ Chip cocoons under previous-year bark ▪ Two years of growth killed	Throughout host range.

Insecticides and pheromones. Insecticides, both contact and systemic, have not effectively controlled this insect. However, an "attract and kill" product is effective and available commercially. It attracts male moths using pheromone bait, then kills the moth with a contact insecticide.

This product is hand-applied in mid-March, before moths emerge. Aerially dispersed pheromone flakes, for mating disruption, are also being evaluated for treating larger plantations.

White pine weevil (Sitka spruce weevil)

Although called the white pine weevil, this insect infests spruce trees in the western United States. Sitka and Engelmann spruces are hosts. Infestations cause tip dieback, reduced height growth, and deformed trees.

Weevil attacks can begin when trees are 3 years old and can increase until 30 to 50 percent of the trees are attacked annually. Infestations begin to decrease at about age 20, but low levels of weevil attack (less than 10 percent of the trees attacked annually) can persist beyond age 40. In general, stands that are 4 to 30 feet tall are the most susceptible.

Weevils seek out the fastest growing trees and kill both current- and previous-year terminal growth. Stand volumes can be reduced by 15 to 40 percent over the stand's lifetime, and affected trees can be severely deformed.

In Sitka spruce, damage is likely to increase the farther a stand is from the coast, the lower its elevation, and the farther south it is. Elevation has the greatest influence, however. Damage also is likely to increase as tree growth rates increase.

Damage is less with lower temperatures and higher humidity, which reduce moisture stress and thereby increase host trees' defensive abilities. Damage also is likely to decrease as spruce density increases, probably because laterals can assume dominance more quickly at the higher densities or because the slower growth rate delays subsequent attacks. Microclimate conditions caused by high-density planting also appear to affect the way weevils search for and find host trees.

Management strategies

There is no easy solution for controlling this damage. However, strategies for Sitka spruce include matching spruce to sites where spruce grows best (the fog belt), stocking control, and, in the future, planting genetically improved stock. Dense stands growing near the coast or in the fog belt (usually, within 5 miles of the coast) appear to have good form after 20 years. Studies indicate that Sitka spruce growing within the fog belt has the lowest levels of weevil attack, while stands growing along inland river valleys have the highest.

Stand management. In pure spruce plantations, plant no wider than 9 by 9 feet, and delay precommercial thinning until age 25. The close spacing will not prevent weevil damage, but it will stimulate height growth, improve tree form, and create a less favorable microclimate for the weevil (Figure 5-2, option 1).

Another option being studied, particularly for more inland sites in the Coast Range, is based on studies in British Columbia. This option is to grow Sitka spruce under an overstory of hardwoods such as red alder (Figure 5-2, option 2). This should decrease weevil attacks, possibly because shaded spruce grow more slowly and are less succulent, and because shade affects weevil behavior. This, plus lower temperatures, should reduce spruce susceptibility. The drawback is reduced spruce growth. This strategy relies on finding a balance or compromise between the volume loss due to overstory competition and volume gain due to reduced attacks.

Other approaches under development include planting spruce and hemlock and/or western redcedar at high densities on sites where both species grow comparatively well, which typically is a site close to the coast or in the fog belt.

Planting stock improvement. Genetic improvements in planting stock are another management option. Seed collected from trees tolerant to weevil damage is being tested in several Pacific Northwest locations. This approach shows promise and may be a good alternative to consider in the future. At this time, genetically improved planting stock is not available from local nursery sources.

Sanitation. On small acreages, sanitize by cutting and burning infested terminals before August, to prevent weevil emergence and to keep populations lower. You may need to repeat this step annually until the spruce is tall enough that it becomes impractical. To improve the form of infested trees, trim off all but one of the lateral shoots in the whorl just below the dead terminal. The remaining branch will turn up and become the new terminal leader.

Insecticides. Contact-insecticide sprays are effective only on adults; all other life stages occur inside the leader. Apply to the leader and upper branches in spring as adults begin to feed and lay eggs. Systemic insecticides can be used to kill larvae feeding within the leader. Consult the current-year edition of the *Pacific Northwest Insect Management Handbook* for specific recommendations.

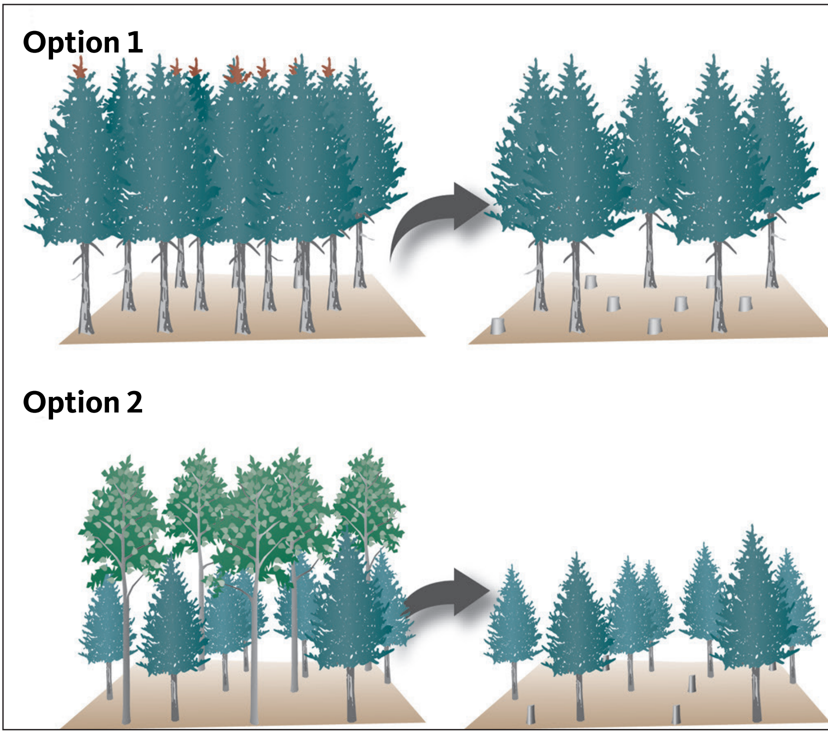

Illustration: Gretchen Bracher

Figure 5-2. White pine weevil management for Sitka spruce. Option 1: Plant at high densities (no wider than 9 by 9 feet) and grow for 20 to 25 years before thinning. The closer spacing helps infested trees grow upward. A late thinning removes many of the infested trees; however, some growth will be sacrificed because of the late thinning. Option 2: For stands more inland, an alternative is growing spruce under a hardwood canopy. Shading the spruce tops may reduce weevil attacks. When removing the overstory, timing is critical. Spruce tops can be damaged if they get banged around in the hardwood canopy. A trade-off with this approach is slower spruce growth than in open-grown stands.

Douglas-fir twig weevil

The Douglas-fir twig weevil commonly attacks young, open-grown Douglas-fir weakened by environmental stress, improper planting, or poor site conditions such as clay soils in the Willamette Valley or low-elevation and droughty sites in southwest Oregon (Figure 5-3, page 63). Trees with stem cankers also are associated with this weevil. Branches and terminal shoots die after attack. Attacks to the terminal shoot reduce height growth and cause forking or poor form.

At times in western Oregon, smaller seedlings have been killed.

Usually, the seedlings were improperly planted ("J-rooted") or had a poor root-to-shoot ratio. Damage is most severe during drought and on dry sites.

The Douglas-fir twig weevil frequently acts with Phomopsis canker to kill Douglas-fir seedlings and saplings during or just after droughts, especially on low-elevation sites and sites with shallow soils and south or west aspects.

Management strategies

Natural factors, such as larval parasites and host resistance, are important for keeping weevil populations in check, but normally it takes parasites a year or more to "catch up" to elevated weevil populations and reduce them. Clipping and destroying infested branches before June—while immature stages of the weevil are still in the twigs—also helps keep pest numbers down.

More intensive management involves good site preparation, properly matching species to site, planting properly (no J-roots), controlling competing vegetation, and thinning to promote vigorous growth. High-vigor trees can tolerate infestations better and are less susceptible to attacks. Once trees reach 15 to 20 feet high, they are no longer at high risk of appreciable damage from this insect.

Species selection. Before planting, assess site resources; then match the best adapted species to the site. For example, on tougher sites, such as where soils are wet, or on drier sites in the Willamette Valley, consider planting Willamette Valley ponderosa pine. This species is better adapted to these tough sites than Douglas-fir is. The Douglas-fir twig weevil will greatly impact Douglas-fir on sites below 3,000 feet elevation in southwest Oregon and can limit the practicality of managing Douglas-fir on these low-elevation sites.

Lodgepole terminal weevil

The lodgepole terminal weevil infests the terminal shoots of lodgepole pine. Once the terminal shoot dies, it is replaced by lateral branches, which creates a deformed, forked top. Most damage is on open-grown, even-aged stands of trees 1 to 30 feet tall.

Management strategies

In most cases, treatments to reduce damage are not necessary. However, on small acreages, cultural practices such as removing and destroying damaged terminals by midsummer will reduce weevil populations. Also, you can improve tree form on infested trees by trimming off all but one of the lateral shoots in the whorl just below the dead terminal. The remaining branch will turn up and become the new terminal leader. Otherwise, rogue out deformed trees during thinning but avoid creating open-growth stand conditions.

Sequoia and Douglas-fir pitch moths

When moth larvae feed (feeding occurs for 1 to 2 years), they cause large, unsightly pitch masses on tree trunks and branches. This is mainly an aesthetic problem but may also cause a degradation in lumber quality. The effect on tree health usually is relatively minor.

Larval feeding typically does not girdle the trunk and rarely kills trees, though repeated attacks on smaller trees may occasionally result in girdling and tree death. In some cases, severely attacked trees will lose vigor and become more susceptible to other pests such as bark beetles. Repeated attacks in the same area of the trunk or branch can cause a weak point.

The adult flight period can extend from May to September. Pruning wounds or other injuries attract egg-laying females, and trees with open wounds are attacked much more frequently than uninjured trees.

Photos: Alan Kanaskie, Oregon Department of Forestry

Figure 5-3. Douglas-fir twig weevil damage to young Douglas-fir trees can reduce height growth and cause forking or poor form.

Damage is more abundant in urban sites and, in particular, in off-site or non-native plantings; that is especially the case with sequoia pitch moth on pines. See Chapter 7, page 89, for proper pruning guidelines.

Management strategies

Management guidelines are:

- Prune when branch diameter is small, to promote rapid wound healing.
- Prune in late fall and winter, after the adult insect's flight period. First, check locally to see if this insect is a known issue in the area. Where it is not, timing of pruning may not be relevant.
- Avoid off-site plantings.
- Keep tree vigor high to increase the trees' ability to tolerate damage.
- Avoid damaging trees and avoid pruning during spring and summer.
- Prune outside the branch collar to promote rapid healing.
- Don't damage the bole during logging, thinning, or construction.
- Maintain tree vigor when pruning by removing no more than one-third of the live crown and retaining at least half the total tree height in live crown.

No insecticide has proved effective in controlling pitch moth attacks. Removing the pitch masses and destroying the single larva inside may help reduce populations and damage to high-value trees.

Gouty pitch midge

Midge larvae feed under the bark of small terminal twigs. Feeding can distort branch tip growth or injure or kill terminal shoots on the host, primarily ponderosa pine. Trees of any age can be attacked. Most severe damage is mostly to trees under 16 feet tall in rather open stands. Damage first appears in early summer and can continue throughout summer. Dead twig ends usually are scattered throughout the tree's crown, making it look "flagged" with bunches of yellow or red needles.

Severe attacks can slow tree growth. Repeated attacks can kill trees, especially younger and smaller ones, but that is rare. More commonly, repeatedly attacked trees may be stunted and severely deformed with multiple leaders.

Use of off-site planting stock and soil compaction are believed to be associated with gouty pitch midge damage. Planted trees are more likely to be attacked than naturally regenerated ones.

Research shows that certain genetic families of ponderosa pine are more susceptible to this insect than others. Those families with resinous shoots are more prone to attacks, and shoot condition is highly heritable.

The midge life cycle is 1 year, and populations fluctuate widely from year to year.

Management strategies

Management information is minimal. We know that individual host trees' susceptibility to this insect can be quite variable. Collecting seed from trees that show resistance should lower stand susceptibility over time. Keeping tree vigor high, such as by thinning, and matching species to site conditions should increase tree and stand resilience to attack.

> ***Use pesticides safely!***
>
> - *Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.*
> - *Read the pesticide label—even if you've used the pesticide before. Registrations may change or be withdrawn at any time. Follow closely the instructions on the label (and any other directions you have).*
> - *Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.*

Dave Shaw, © Oregon State University

Defoliated ponderosa pines exhibit the “lion’s tail” effect, where foliage is confined to the tips of branches.

Chapter 6

Root Diseases[7]

Forest root diseases are among the most difficult groups of pests to identify, quantify, and manage in the Pacific Northwest. Root disease is caused by fungi and related organisms (pathogens) that attack and kill the tree's root system (Table 6-1, page 68). Trees affected by root disease also are more susceptible to bark beetles and wood borers.

Although single trees can be affected by root diseases, disease usually is indicated by groups of dead, dying, and often windthrown trees called disease patches, disease centers, or canopy gaps. These groups become larger over time, ranging from a few trees to many trees across hundreds of acres, as the disease-causing organisms spread from tree root to tree root.

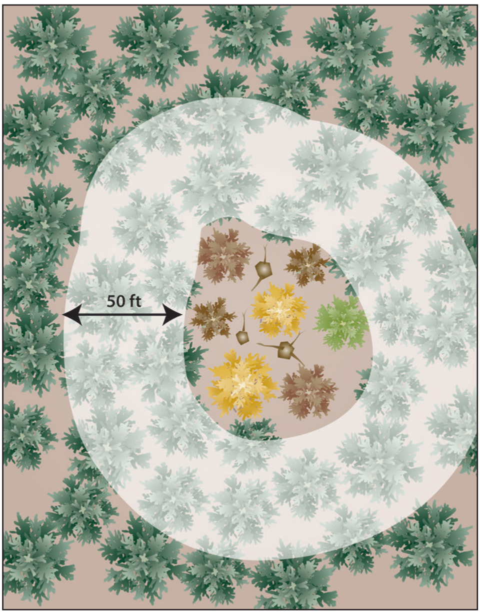

Illustration: Gretchen Bracher

Figure 6-1. Laminated root rot can be treated by identifying the disease centers in your stand and harvesting all susceptible trees within the center and within a buffer that's at least 50 feet wide. If the outer boundaries of root disease centers are within 100 feet of each other, treat the two disease centers as one.

Tree species vary in their susceptibility to infection by root pathogens and associated damage (Table 6-2, page 70). Hardwoods are not affected by laminated root rot, black stain root disease, or Port-Orford-cedar root disease—three of the five most important root diseases in the Pacific Northwest. Although Armillaria and Heterobasidion (formerly called annosus) root diseases are known to affect both conifers and hardwoods, crossover is thought to be uncommon. This is why suitable hardwoods often are recommended to plant or favor in many root-disease areas.

[7] Goheen & Willhite, 62–87

Table 6-1. Important forest root diseases in Oregon: Hosts, key identifiers, and distribution.

Root disease and cause	Major hosts	Key identifiers	Distribution
Laminated root rot *Phellinus sulphurascens* (*P. weirii* is the former name)	Douglas-fir, true firs, mountain hemlock	▪ Laminated decay ▪ Ectotrophic mycelia ▪ Setal hyphae	Throughout host range, especially west of Cascades, but uncommon in eastern Oregon; occurs in the area south of the Crooked River and east of Hwy. 97
Armillaria root disease *Armillaria ostoyae*	Douglas-fir, true firs, hemlock, pine, spruce	▪ Mycelial fans ▪ Rhizomorphs ▪ Yellow-stringy decay	Throughout host range; susceptibility varies with locale
Heterobasidion root disease *Heterobasidion occidentale* on fir, spruce, and hemlock *H. irregulare* on pines (*H. annosum* is the former name)	True firs, pine, hemlock, spruce	▪ Hidden conks ▪ Ectotrophic mycelia ▪ Laminated or stringy decay	Throughout host range, especially east of Cascades and in southwest Oregon Mostly a butt rot of hemlock and spruce along the coast; tree killer and butt rot of true firs in the dry forests May be locally important in pine
Black stain root disease *Leptographium wageneri*	Douglas-fir, ponderosa pine	▪ Black stain in wood limited to one to three growth rings, but no decay	Douglas-fir west of the Cascades; ponderosa pine east of the Cascades
Port-Orford-cedar root disease *Phytophthora lateralis*	Port-Orford-cedar	▪ Brown stain in inner bark, but no decay	Throughout host range in southwest Oregon

Survey and management principles

Survey principles

Before you can manage any root disease, you must identify the type of root disease and map disease locations systematically. First, look for above-ground symptoms, such as dead trees or thin crowns. Keep in mind, however, that above-ground symptoms indicate only about half the area that is actually infected.

For most root diseases, to learn the full extent of the root disease area, it's a good idea to map disease locations both before and after harvesting a stand (Figure 6-1, page 67). Immediately after felling, look for stain or decay on stump tops. Stain can fade with time, so use a saw to mark infected stump tops with parallel or crossed lines. While mapping, also record the species and diameters of affected trees. To survey for Port-Orford-cedar root disease, look for the characteristic brown stain on the inner bark of declining trees.

Management principles

The main ways to manage forest root diseases are:

- Reduce pathogen survival.
- Remove the pathogen or limit its means of spreading.

All root diseases spread by root-to-root contacts: the pathogen grows from an infected root of a tree or stump to a root on a healthy tree (Figure 6-2, page 71, and Table 6-3, page 75). In general, disease patches expand radially by about 1 to 2 feet a year, except for black stain and Port-Orford-cedar root diseases, which can spread much faster.

One strategy to stop spread is to break the chain of root contacts between healthy and infected trees, either by spacing trees through thinning, by removing stumps, or by planting and managing resistant and immune tree species between the infection center and healthy leave trees. However, it is difficult to determine whether a tree is healthy or infected if it has no above-ground symptoms.

Many root-disease pathogens can survive in roots for decades after infected trees have died. Exceptions are black stain root disease and Port-Orford-cedar root disease, where the causal agents die within 1 to 2 years of tree death. If a diseased stand is harvested and replanted with susceptible species, seedlings eventually become infected. Damage in the new stand may be worse than in the preceding stand.

The preferred management strategy is to reduce pathogen survival by taking advantage of the differences in tree species' susceptibility to root diseases (Table 6-2, page 70). If you plant or regenerate tolerant or resistant tree species (susceptibility classes 3 and 4) for 50 years or more, and you periodically remove regeneration of more susceptible species (susceptibility classes 1 and 2), root-disease pathogens should die over most of the infected area. Subsequent rotations of susceptible species aren't likely to be reinfected.

If you plant or favor tree species in susceptibility class 2 in root-disease areas, trees will become infected but at levels lower than tree species in susceptibility class 1 would have been. Planting or favoring hardwoods, especially on sites affected by laminated root rot, has good potential to reduce disease after several decades.

Table 6-2. Relative susceptibility of Pacific Northwest conifers to damage by root diseases.

	Laminated root rot	Armillaria root disease	Heterobasidion root disease	Black stain root disease	Port-Orford-cedar root disease
Douglas-fir (coastal)	1	2	3	1	4
Douglas-fir (interior)	1	1	3	3	4
Fir (grand, white)	1	1	1	4	4
Fir (Pacific silver)	2	2	1	4	4
Fir (noble, red, subalpine)	2	2	2	4	4
Hemlock (mountain)	1	2	1	3	4
Hemlock (western)	2	2	2	3	4
Incense-cedar, juniper, redwood	4	3	3	4	4
Larch (western)	2	3	3	4	4
Pine (ponderosa, Jeffrey, lodgepole)	3	2	2	3	4
Pine (knobcone, sugar, white)	3	2	3	3	4
Port-Orford-cedar	4	3	3	4	1
Redcedar (western)	4	2	3	4	4
Spruce (Engelmann)	2	2	3	4	4
Spruce (Sitka)	3	2	3	4	4

1 = severely damaged, 2 = moderately damaged, 3 = seldom damaged, and 4 = not damaged. Ratings based on field observations in the Pacific Northwest.

Management options

Partial cutting

Partial cutting—commercial and precommercial thinning and seed-tree and shelterwood harvesting—has advantages and disadvantages in managing forest root diseases, especially in Douglas-fir and ponderosa pine.

Advantages are:

- Wounded and infected trees can be eliminated.
- If trees are spaced early enough and widely enough, root-to-root contact and subsequent disease spread among remaining trees will be minimized.
- Tree growth and vigor will improve, which in turn increases their resistance to certain root diseases.
- Root-disease-tolerant species can be favored.

Some disadvantages:

- Black stain root disease may increase in Douglas-fir stands that are thinned before June 1 or after September 1.
- Stumps from harvesting, especially larger stumps, can become inoculum sources for *Armillaria* or *Heterobasidion* root diseases.
- Windthrow can increase in root-diseased areas.

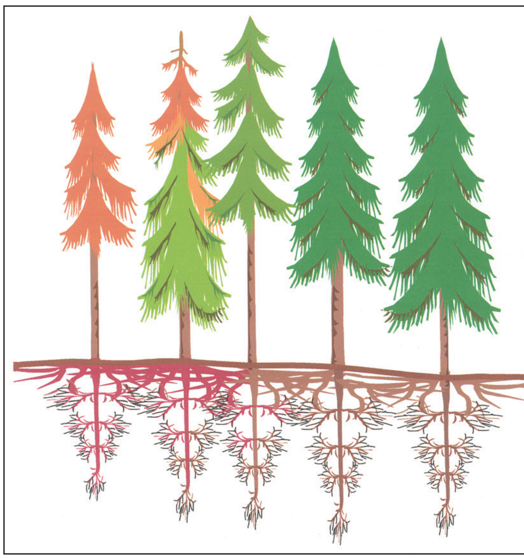

Illustration: Nancy Boriak

Figure 6-2. Root diseases spread from diseased trees to healthy trees by root contact.

Sanitation-salvage cutting

The main advantages of sanitation-salvage cutting are:

- Root-infected trees and trees at high risk of dying are removed.
- The economic value of dead and dying trees is recovered.

Photo: Greg Filip, U.S. Forest Service

Figure 6-3. Uneven-aged management, which creates stands by repeatedly harvesting and establishing susceptible regeneration, can foster the spread of root disease from infected stumps to adjacent seedlings and saplings.

The disadvantage to cutting living, infected trees is that it can increase some root diseases in two ways.

First, living trees have defense mechanisms that prevent root pathogens such as *Armillari*a or *Heterobasidion* from advancing to the root collar and killing the tree. Dead trees lack these mechanisms, and root pathogens quickly spread throughout the entire root system after the tree dies or is harvested. This spread increases infection and death of adjacent trees.

Second, in the case of *Heterobasidion* root disease, partial harvest of living, uninfected trees exposes living wood on newly cut stumps or trunk wounds. Exposed wood, in turn, provides an infection point for spores of the *Heterobasidion* fungus, and thus infections on the site can increase.

Clearcutting and regeneration

Clearcutting usually presents fewer root-disease management problems than other types of regeneration harvesting, such as seed-tree and shelterwood harvesting, because clearcutting leaves few or no large trees to windthrow as a result of root disease or to damage regeneration if they are harvested later.

However, root disease may spread from infected stumps to susceptible regeneration within the clearcut unit. Mark infected stumps as you map root-disease areas (see “Survey and management principles,” page 69), and plant resistant or tolerant species in those areas.

The tree species and the type of regeneration—planted, natural, or advance—will determine the amount of potential disease damage:

- Planted regeneration allows you to select disease-resistant species. However, seedlings should be from seed gathered in appropriate seed zones.
- Natural regeneration may foster the spread of root diseases if highly susceptible species are allowed to regenerate.
- Advance regeneration may already be infected with root pathogens before the overstory is harvested and, therefore, poses the greatest risk of future root disease.

Retaining infected living trees and snags within clearcuts will influence root-pathogen populations and the number of new host trees in the future stand.

Uneven-aged management

Root diseases are affected by stand structure and composition. Silvicultural systems, such as uneven-aged management, that produce and maintain multistoried stands and shade-tolerant climax tree species (especially true firs) generally allow root disease to increase (Figure 6-3). Also, harvesting large, living, infected trees may aggravate root disease on a site. Thus, uneven-aged management that uses repeated harvests and susceptible regeneration may perpetuate and worsen some kinds of root disease.

Reduce root disease in multistoried stands by:

- Favoring resistant and tolerant tree species when thinning and replanting
- Thinning to improve and maintain tree vigor
- Treating freshly cut stumps to prevent infection from *Heterobasidion* spores on true firs and ponderosa pine (see “Heterobasidion root disease,” page 77)

Prescribed burning

Prescribed burning has been used for many years, especially on the east side of Oregon, to reduce fuels and remove unwanted understory vegetation, but fire has not been shown to control root diseases. Some have suggested that fire might prevent *Heterobasidion* spore infection if stumps are burned within 24 hours of cutting and might reduce black stain root disease by killing bark beetle and weevil vectors in the duff around trees and stumps. However, more research is needed in the Pacific Northwest on fire's effects, both positive and negative, on the incidence of root diseases and associated bark beetles in residual trees and subsequent regeneration. The main effect of prescribed burning is probably that it favors fire-tolerant species and, perhaps, disease-resistant species.

Stump excavation

Stump excavation has been used infrequently to prevent and reduce laminated root rot and Armillaria root disease in the Pacific Northwest. Although its effectiveness is unproven, removing infected stumps should reduce incidence of root disease on an infected site over time, even when tree species are highly susceptible.

Advantages of stump excavation include:

- It removes infected stumps and large roots and minimizes disease spread to the new regeneration.
- Mortality of leave trees or planted seedlings is reduced.
- The growth rate of leave trees increases.
- Highly susceptible but economically valuable tree species are less risky to grow after stump excavation.

Disadvantages are:

- Stump excavation is expensive and requires special equipment.
- Stump excavators may compact heavy or waterlogged soils.
- Excavated stumps are unsightly and may need to be removed from the site or be piled and burned.
- Erosion might increase on steeper slopes.

Chemical control

With one exception (see "Heterobasidion root disease," page 77), chemical control has not been widely used to manage forest root diseases in the Pacific Northwest. Many treatments are still experimental and need further testing.

Experiments using fertilizers to control root diseases have had mixed results. The thought was that applying fertilizer would improve tree vigor and thus reduce infection and mortality caused by some root pathogens. Currently, fertilizer is not recommended to reduce or prevent root disease.

Management strategies for specific root diseases

Laminated root rot

Laminated root rot is the most damaging root disease in Oregon, especially west of the Cascade crest (see Table 6-1, page 68). The disease

Table 6-3. Method of spread and management strategies for the major forest root diseases in Oregon.

Root disease	Method of spread	Management strategies
Laminated	Roots	▪ Favor resistant species. ▪ Thin to decrease root contacts. ▪ Excavate stumps.
Armillaria	Roots	▪ Prevent soil compaction and tree wounding. ▪ Favor resistant species. ▪ Thin to increase tree vigor.
Heterobasidion	Air, roots	▪ Treat stump surfaces. ▪ Prevent tree wounding. ▪ Favor resistant species.
Black stain	Insects, roots	▪ Prevent tree wounding and soil compaction. ▪ Thin between June 1 and Sept. 1. ▪ Do not thin if disease is prevalent. ▪ Favor resistant species.
Port-Orford-cedar	Water, soil, roots	▪ Avoid infested areas. ▪ Clean logging equipment. ▪ Remove roadside cedars. ▪ Favor resistant species. ▪ Plant resistant cedars.

is identified in roots and butts by the presence of typical laminated decay, ectotrophic (root surface) mycelia, and brown setal hyphae (hairlike fungal structures).

Management strategies

Three effective methods can be used to manage laminated root rot:

- Favoring resistant species
- Early thinning to decrease root contacts
- Excavating infected stumps

It should be noted that before implementing any management method, survey your stand. If there are only one or two root-disease centers, you might be safe in ignoring the problem. If less than 5 percent of the site is affected, it may be more economical to leave the problem alone.

Favoring resistant species. In many cases, laminated root rot can be managed by favoring several resistant or tolerant tree species when planting or thinning to discriminate against the highly susceptible Douglas-fir or true firs (Table 6-2, page 70).

Thinning. Young (less than 10 years old) Douglas-fir stands that are less than 5 percent affected by laminated root rot can be precommercially thinned to a spacing of 13 feet. In coastal Douglas-fir sites with deep soils, research has shown that there are few root contacts to spread infection among trees aged 60 years or less and spaced at least 13 feet apart. Although some trees will contact residual inoculum and die from laminated root rot, secondary infections will be reduced by thinning.

If disease centers are numerous and widely distributed, as in stands more than 10 years old, these stands may have to be destroyed and replanted with resistant species.

In older stands that may be commercially thinned, do not thin stands in which laminated root rot affects more than 20 percent of the trees. Such stands may need to be completely harvested and planted with resistant species.

In older stands with less than 20 percent root disease, you can

- thin as normal if windthrow risk is low and if you will harvest in 15 years,
- remove all trees including those within 50 feet of visibly infected trees or stumps, or
- thin in areas with high windthrow risk except for any trees within 50 feet of visibly infected trees and stump.

Excavating infected stumps. If it is desirable or necessary to grow Douglas-fir, stumps of harvested and infected trees can be excavated and removed and sites replanted with Douglas-fir. On gently sloping, high-quality sites with light soils, removing stumps with a wide-tracked excavator can effectively manage laminated root rot.

Fumigating. Fumigation to eradicate the causal fungus from infected stumps and even from living trees has been done experimentally in Oregon and Washington. The fungus can be eliminated from Douglas-fir stumps with chloropicrin, allyl alcohol, Vapam, or Vorlex. Long-term effectiveness of stump fumigation, however, is still being evaluated. One study in Washington found that 20 years after fumigation, there was no disease control in planted seedlings.

Armillaria root disease

Armillaria root disease is the most common forest root disease in Oregon (Table 6-1, page 68). Armillaria is diagnosed by the presence of mycelial fans, rhizomorphs (black, root-like fungal structures), and yellow-stringy decay. Although Armillaria-caused mortality has long been associated with low-vigor trees, major damage can occur in stands that look healthy, especially stands east of the Cascade crest.

Management strategies

Several effective methods can be used to manage Armillaria root disease:

- Favoring resistant species
- Thinning to decrease root contacts and increase tree vigor
- Preventing tree wounding, soil disturbance, or other activities that reduce tree health (Table 6-3, page 75)

Favoring resistant species. Although the causal fungus has the widest host range of any of the Oregon root diseases, in many cases Armillaria root disease can be managed by favoring resistant or tolerant tree species (Table 6-2, page 70). However, since Armillaria often is associated with low-vigor trees, forest operations that increase tree vigor will reduce mortality caused by Armillaria root disease even in susceptible tree species.

Thinning. Precommercial thinning in ponderosa pine and Douglas-fir has reduced tree-growth loss and mortality caused by Armillaria in Oregon. Commercial thinning of ponderosa pine also shows promise in reducing Armillaria damage, but long-term effects are still being evaluated. Do not thin older stands that are more than 20 percent affected by Armillaria root disease. Such stands may need to be completely harvested and planted with resistant species.

Preventing other activities that reduce tree health. Follow wound-prevention guidelines (Chapter 7, page 82) when thinning and harvesting. Take care during selective or salvage cutting since these techniques have a long history of exacerbating Armillaria root disease, especially if leave-tree species are in susceptibility classes 1 or 2 (Table 6-2, page 70). Also, minimize soil damage to reduce damage from Armillaria root disease.

Other practices. Some experimental work has been done with stump excavation, fumigation, and inoculation, but long-term effects and economics are still being evaluated.

Heterobasidion root disease

Heterobasidion root disease usually occurs where susceptible species have been partially harvested or when trees have been wounded, especially in older stands (Table 6-1, page 68). In addition to root disease, the fungus also causes stem decay (see Chapter 7). Heterobasidion is identified by the presence of hidden conks, ectotrophic mycelia, and typical laminated or stringy decay.

Management strategies

Several methods can be used to manage Heterobasidion root disease:

- Favoring resistant species
- Preventing tree wounding, soil disturbance, or other activities that wound trees and decrease tree vigor
- Treating stump surfaces with a boron-containing product (Table 6-3, page 75)

Favoring resistant species. In many cases, Heterobasidion root disease can be managed by using several resistant or tolerant tree species when planting or thinning (Table 6-2, page 70). One *Heterobasidion* species (*H. occidentale*) affects spruce, Douglas-fir, true fir, and hemlock; the other species (*H. irregulare*) affects pine, larch, cedar, juniper, and redwood. The fungus rarely spreads between the species groups.

Preventing activities that decrease tree vigor. Thinning or partial harvesting may increase residual-tree infection and mortality when spores from the *Heterobasidion* fungus infect freshly exposed living wood, such as freshly cut stump tops or new trunk wounds. Follow wound prevention guidelines (Chapter 7, page 82).

Treating stumps. Application of boron-containing products to protect stumps from Heterobasidion root disease has been successfully demonstrated and is operationally used in the Pacific Northwest. Currently, only Sporax (sodium tetraborate decahydrate) is EPA registered.

To be effective, the chemical must be sprinkled on the stump surface within 24 hours after cutting, and it prevents infection only if the stump was not previously colonized by *Heterobasidion* (i.e., no visible stain or decay). Minimum stump diameter to treat is 12 inches; smaller stumps are not effective sources of infection in forest stands. True firs and ponderosa pine are the only major species that may need boron stump treatments, and true firs only when they are being managed or retained.

Biological control with stump treatments such as antagonistic fungi (e.g., *Phlebiopsis gigantea*) are used routinely in Europe to protect conifer stumps from the *Heterobasidion* fungus, but work in North America is only experimental, and no agents are registered for operational use.

Black stain root disease

Black stain root disease is an insect-vectored root disease that has two types in Oregon: one may be found in young Douglas-fir stands that have been thinned and the other in older ponderosa pine stands (Table 6-1, page 68). Black stain root disease is identified by the typical black stain without decay in the first one to three growth rings of the root sapwood.

Management strategies

The main methods of managing black stain root disease are:

- Favoring resistant species
- Thinning between June 1 and September 1 (or do not thin if disease is prevalent)
- Preventing tree wounding, soil disturbance, or other activities that decrease tree vigor and attract insect vectors (Table 6-3, page 75)

Favoring resistant species. In many cases, black stain root disease can be managed by using several resistant or tolerant tree species, since several species are not affected by the disease (Table 6-2, page 70). Also, one strain of the fungus attacks only Douglas-fir, and the other strain attacks only pines and hemlocks; there is no crossover.

Thinning. Current recommendations include thinning Douglas-fir plantations with black stain root disease after June 1, when bark-beetle vectors are not flying. Thin before September 1 so thinned material can dry before winter and be unsuitable for insect vectors in spring. However, in some cases it may be best to forgo thinning altogether if disease is widespread in the plantation. Follow wound prevention guidelines (Chapter 7, page 82).

Preventing activities that decrease vigor and attract insect vectors. When harvesting stands with black stain root disease, design harvest systems that minimize soil disturbance, such as high-lead or skyline systems, rather than tractor logging. In addition:

- Regenerate skid trails with resistant species.
- Avoid creating flooded or poorly drained areas in plantations or established stands during road building or maintenance.
- Do not create patches of wounded or stressed host trees by pushing new roads through established stands or by cutting brush along roadsides.

Port-Orford-cedar root disease

Port-Orford-cedar root disease is unique to Port-Orford-cedar forests in southwest Oregon and northwest California (Table 6-1, page 68). The disease is diagnosed by the brown-stained inner bark of infected roots and butts. The causal agent is a water mold that is transported in infested soil along roads and waterways.

Management strategies

Port-Orford-cedar root disease can be managed using a variety of methods:

- Favoring resistant species
- Avoiding infested areas
- Cleaning logging equipment
- Removing roadside cedars
- Planting resistant cedars

Favoring resistant species. All other tree species, except for Pacific yew, are not affected by Port-Orford-cedar root disease, so favor them when planting, thinning, or removing cedar in diseased areas.

Avoiding infested areas. Because Port-Orford-cedar root disease is our only non-native forest root disease, limited quarantines can prevent disease spread. Vehicles carrying infested soil are known to be the main method of disease spread. Restrict the movement of vehicles through infested areas or gate roads to prevent entry, especially during wet periods.

Cleaning logging equipment. Vehicles and logging equipment can be washed before or after entering infested areas at nearby washing stations.

Removing roadside cedars. Removing cedars from roadsides minimizes spread of the disease from infested soil deposited along roads if no cedars remain along the infested road. All cedar seedlings, saplings, and even larger trees should be girdled, felled, pulled, or burned 25 feet above the road and 25 to 50 feet below the road. Distances should be greater where streams or drainages cross the road.

Planting resistant cedars. Breeding cedar seedlings resistant to Port-Orford-cedar root disease has been successful and is used operationally in Oregon and California. The long-term success of this strategy is still being evaluated. Resistant stock is not immune to the disease, and some trees will be infected and die in heavily infested areas. Therefore, critically evaluate use of resistant seedlings because of their additional cost and the likelihood of their harboring disease that may spread to adjacent areas. Resistant seedlings can be purchased from some commercial nurseries.

Chapter 7

Stem Decays[8]

Stem decay in living trees is caused by various species of fungi that enter trees through wounds or small branches. Decay fungi usually do not kill trees, and small amounts of decay will not affect tree growth significantly. However, decay greatly diminishes the value of forest products. In addition, decayed trees are structurally weakened and more likely to break during storms or harvest. Decayed trees can be serious hazards when near roads, buildings, or developed recreation areas. On the positive side, decay of living trees is a natural forest process that recycles nutrients and creates important wildlife habitat in standing trees and down logs, both on land and in streams.

Photo: Greg Filip, U.S. Forest Service

Figure 7-1. Conk of the Indian paint fungus on an infected true fir.

Many decays can be recognized by conks on the tree stem (Figure 7-1). A conk is a specialized structure produced by wood-decay fungi to disperse spores. Usually, considerable wood decay is behind the conk. In general, the more conks or the bigger the conk, the larger the amount of decay. The amount of decay associated with conks (and other external indicators) varies among the fungus and tree species. Important forest stem decays in Oregon are summarized in Table 7-1 (page 83).

Management strategies

How you decide to manage stem decays depends on your objectives for the stand or forest. If you want highest timber production or want to ensure trees' structural integrity (i.e., avoid hazard trees), you can follow guidelines (below) to minimize stem decays. On the other hand, do the opposite if you want a certain amount of stem decay both in living trees or in future snags and down woody material (see "Facts about stem decays," page 84).

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[8] Goheen & Willhite, 88–119

Wound prevention

To minimize stem decay, prevent tree wounding when thinning, burning, disposing of slash, and removing the overstory, both in planning and during the actual harvest operation. Also:

- Avoid spring and early summer logging, when bark is soft and loose.
- Match the size and type of operating equipment with site topography, tree size, and soil type and condition.
- Mark leave trees rather than trees to be cut so that leave trees are easier to distinguish.
- Plan and mark skid trails before logging.
- Match log length with final spacing in the stand: if cutting and skidding long logs, leave trees must be widely spaced; if logs are shorter, leave-tree spacing can be narrower.
- Log skid trails first. Cut stumps low in skid trails to prevent vehicles and logs from being pushed sideways into standing trees.
- Use directional falling and fell to openings. Trees should be felled about 45 degrees toward or away from skid trails and corridors.
- Limb and top trees before skidding.
- Remove slash within 10 feet of leave trees to reduce damage from natural or prescribed fire.
- Ask for the operator's help in preventing tree wounding.

Species selection

Favor decay-tolerant and resistant species (Table 7-2, page 87; susceptibility classes 3 and 4) in uneven-aged management and during a variety of silvicultural operations including planting, using advance regeneration, thinning, prescribed burning, and seed-tree and shelterwood harvesting. If you plant or regenerate tolerant or resistant tree species and periodically remove regeneration of the more susceptible species (classes 1 and 2), decay fungi might infect potential wounds, but subsequent decay will be minimized. If your tree species are in susceptibility class 2, many trees will become decayed but at levels lower than tree species in susceptibility class 1 would be.

Table 7-1. Important forest stem decays, major hosts, and key identifiers in Oregon.

Stem decay and cause	Major hosts	Key identifiers
In live trees		
Brown top rot, or "rosey" top rot *Fomitopsis cajanderi*	Douglas-fir, most other conifers	▪ Rosey colored on underside and edges of conks ▪ Reddish-brown cubical rot
Brown trunk rot *Fomitopsis officinalis* (quinine fungus)	Douglas-fir, pine, larch	▪ Large, white to gray conks ▪ Brown, cubical decay with white mycelial felts
Red ring rot, or white speck *Porodaedalia pini* (*Phellinus* is the former name)	Douglas-fir, grand fir, white fir, mountain hemlock, pine	▪ Bracket-like gray to brown conks with golden-brown angular pores on underside ▪ White specks in a crescent- or ring-shaped decay
Rust-red stringy rot *Echinodontium tinctorium* (Indian paint fungus)	True firs, mountain hemlock	▪ Large, black conks with red interior and "teeth" on underside ▪ Red-stringy decay
Schweinitzii root and butt rot *Phaeolus schweinitzii* (velvet-top fungus, or cow-pie fungus)	Douglas-fir, true firs, pine, larch, spruce	▪ Large, yellow to brown conk with soft, velvety top ▪ Conk with a stalk when growing on the ground but bracket-like when growing on a tree ▪ Brown-cubical decay
In dead trees, dead wood, or down logs		
Brown crumbly rot *Fomitopsis pinicola* (red-belt fungus)	All conifers	▪ Conk with a red to brown upper surface, a white undersurface, and a red belt in between ▪ Brown, cubical rot of the sapwood and heartwood
Gray-brown sap rot *Cryptoporus volvatus* (pouch fungus)	All conifers, especially Douglas-fir, grand fir, and white fir	▪ Conks small, numerous, white to tan, with a lower membrane; resemble ping-pong balls ▪ Soft, grayish sap rot
Pitted sap rot *Trichaptum abietinum* (purple conk)	All conifers	▪ Conks small, numerous, thin, and shelf-like; upper surface gray to black; undersurface violet to purple ▪ Advanced decay with small pits that become elongated in the direction of the grain

Facts about stem decays

- *Amount of decay increases with frequency of tree wounding. Wounds both activate dormant infections and provide openings for spores, which create new infections.*
- *Amount of decay increases with wound size and age. Given trees of the same age and size, basal wounds have more decay than upper-stem wounds.*
- *Amount of decay increases with tree age and with diameter if diameter is directly proportional to age.*
- *Live trees compartmentalize decay; that is, the diameter of the decay column will not exceed the diameter of the tree when it was wounded unless the tree is wounded again (Figure 7-2, page 85).*
- *Amount of decay is greater in nonresinous tree species, such as true firs, hemlocks, and hardwoods. Resinous species such as pines, Douglas-fir, and larch are more resistant to decay.*
- *Amount of decay is influenced by tree genetics. Within a species, some trees can be more resistant to decay than others, all other factors being equal.*
- *Decay may be caused by a single species of decay fungus, but infections by two or more species are common.*
- *Less wood is decayed in trees that have been thinned and/or fertilized compared to trees in unmanaged stands.*

Partial cutting

Partial cutting—precommercial and commercial thinning and seed-tree and shelterwood harvesting— have advantages and disadvantages in managing stem decays.

Advantages are:

- Wounded trees, decayed trees, and trees with broken or dead tops can be eliminated or harvested.
- Leave trees wounded in early thinning will develop smaller decay columns than if they had been wounded later, when they were larger.
- Shorter rotations can be used, thus reducing decay.
- Decay-tolerant species can be favored.
- Leave trees are more resistant to infection by certain decay fungi (e.g., Indian paint fungus) because of increased vigor.

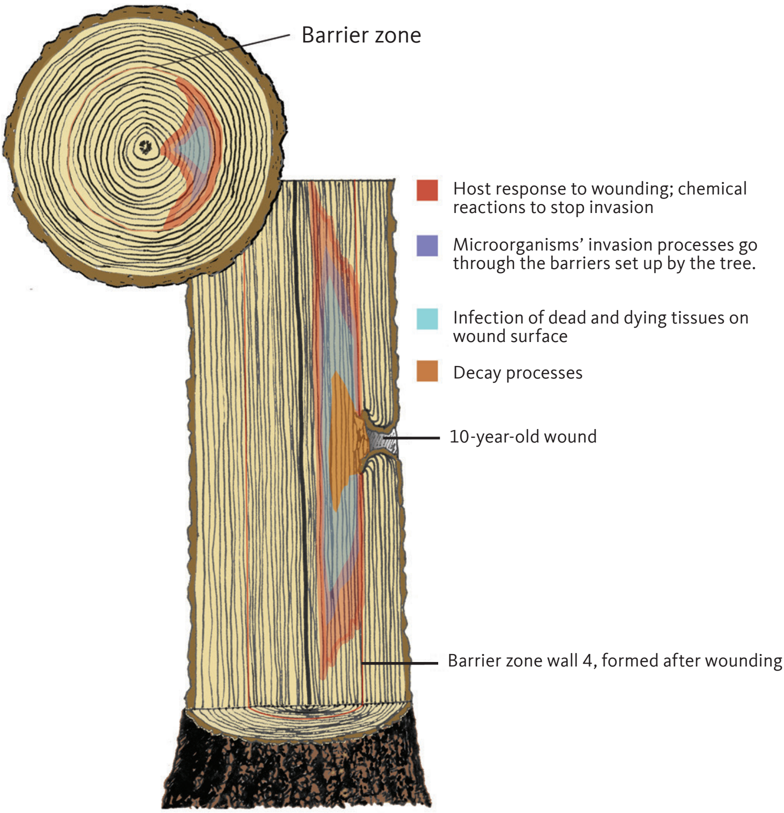

Illustration: Gretchen Bracher

Figure 7-2. Decay associated with a 10-year-old wound often is compartmentalized within a tree.

Disadvantages are:

- Sunscalding of some species (mainly true firs) can occur on certain sites if spacing is too wide. Sunscald kills inner bark and cambium, thus creating a wound that allows decay-fungi spores to enter.
- Slash increases risk from fire, stem wounding, and bark beetle attack.
- Wounding larger trees leads to larger decay columns.
- Wind snap and top breakage may increase, especially in wounded and decayed stands.

Thinning can increase the incidence of stem decay if you don't take steps to reduce tree wounding. On the other hand, the percentage of decay in thinned trees is less because of the extra volume growth added after thinning (Figure 7-3, page 86).

Clearcutting and regeneration

Clearcutting and regeneration present the same kinds of issues for stem-decay management as they do for root-disease management. Clearcutting usually presents fewer stem-decay management problems than other types of regeneration harvesting, such as seed-tree and shelterwood harvesting, because clearcutting leaves few or no large trees to windthrow or break as a result of stem decay or to damage regeneration if they are harvested later.

The tree species and the type of regeneration—planted, natural, or advance—will determine the amount of potential decay damage:

- Planted regeneration allows you to select decay-resistant species. Remember that seedlings should be from seed gathered in appropriate seed zones.
- Natural regeneration may become decayed if highly susceptible species are allowed to regenerate.
- Advance regeneration may already be infected with stem-decay fungi, such as the Indian paint fungus, before the overstory is harvested. Therefore, advance regeneration poses the greatest risk of future stem decay.

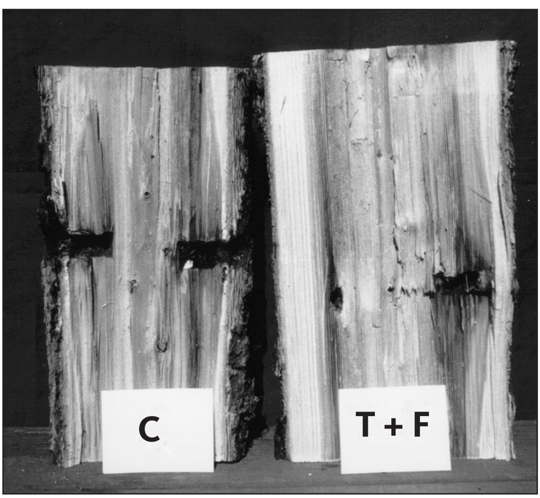

Photo: Greg Filip, U.S. Forest Service

Figure 7-3. Tree wounding may lead to decay, as in these grand firs, where C = control (not thinned or fertilized) and T + F = thinned and fertilized. The percentage of decay, however, will be less in thinned and fertilized trees because the treated trees grow more decay-free wood outside the original decay column.

Table 7-2. Relative susceptibility of Pacific Northwest conifers to stem-decay fungi.

	Rust-red stringy rot Indian paint fungus	Red ring rot	Brown trunk rot Quinine fungus	Schweinitzii root and butt rot Velvet-top fungus	Brown crumbly rot Red-belt fungus	Gray-brown sap rot Pouch fungus	Pitted sap rot Purple conk	Brown top rot
Cedar	4	3	3	3	3	3	1	4
Douglas-fir	4	1	2	1	1	1	1	2
Fir (grand, white, Pacific silver)	1	1	3	1	1	1	1	4
Fir (other true)	2	2	2	2	1	2	1	4
Hemlock (mountain)	1	1	3	2	1	2	1	3
Hemlock (western)	2	2	3	2	1	2	1	3
Larch	4	2	2	1	1	2	1	3
Pine	4	1	2	1	1	1	1	4
Redwood/juniper	4	4	4	4	4	4	4	4
Spruce	3	2	3	2	1	2	1	¾

1 = often decayed, 2 = occasionally decayed, 3 = seldom decayed, and 4 = not decayed

Uneven-aged management

When managing stem decays, uneven-aged management is more appropriate in some forest types, such as pure ponderosa pine, than in others, such as true-fir-dominated forests, because pine wood is relatively more decay resistant (Table 7-2, page 87). Stem-decay fungi spread via airborne spores that either enter fresh wounds or are stimulated by wounding if already present in infected stems. True firs that have been suppressed are more prone than vigorous trees to Indian paint fungus infection. Therefore, if uneven-aged management increases tree wounding (through increased activity in the stand) or increases tree suppression of true firs, then stem decay may increase (Figure 7-4).

Reduce stem decays in multistoried stands by:

- Favoring decay-resistant species (susceptibility classes 3 or 4) in thinning and replanting
- Reducing tree wounding by properly planning and harvesting

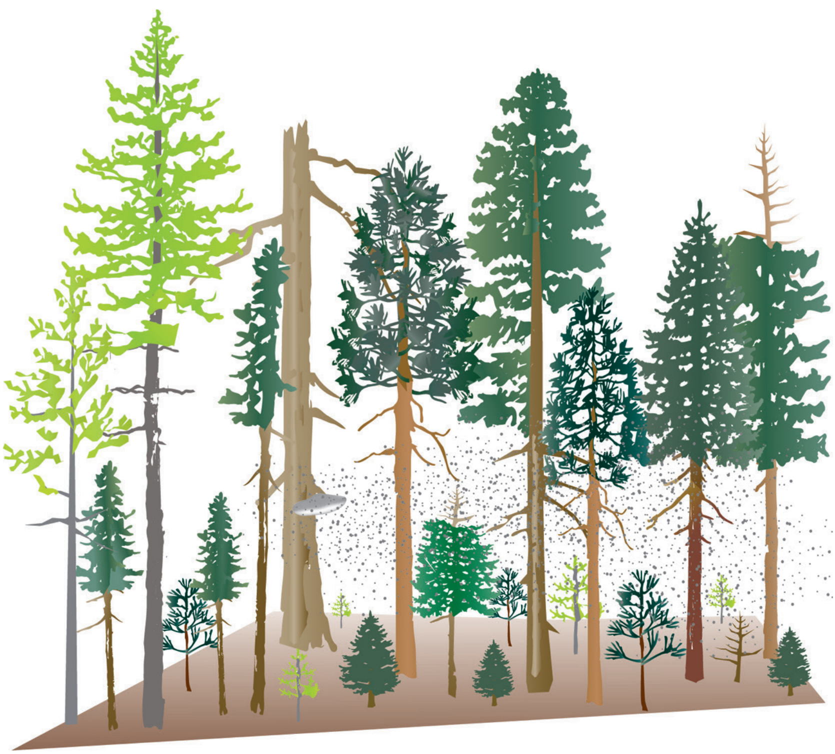

Illustration: Gretchen Bracher

Figure 7-4. Stem infection and decay caused by the Indian paint fungus may increase in true firs that are suppressed in the understory.

Prescribed burning

Prescribed burning in stands of thin-barked tree species, such as white fir, is enough to kill the trees' cambium. This can be associated with stained and decayed wood within 2 years of burning. Before underburning, remove slash within 10 feet of residual trees to reduce stem scorch and subsequent cambial damage.

Branch pruning

Artificial branch pruning usually is combined with stand thinning. Pruned live branches seal faster than pruned dead branches and thus produce fewer boards with knots.

Advantages of pruning are:

- Wood quality and value improve because pruning live branches creates tight knots or no knots in outer wood versus loose knots when dead branches are pruned or shed.
- Stand access improves after thinning.
- Fuel ladders from the ground to trees' living crowns are reduced.
- Some pathogens are eliminated or prevented, for example, white pine blister rust (see Chapter 9, page 107) or dwarf mistletoe (see Chapter 10, page 117).

Disadvantages of pruning, besides the cost, arise mainly from various types of improper pruning. Disadvantages include:

- Improper pruning causes increased stem decay, ring shakes, frost and sun cracks, wetwood, cankers, bark and pitch pockets, and insect attack.
- Rate of tree growth will slow if too many live branches are removed.

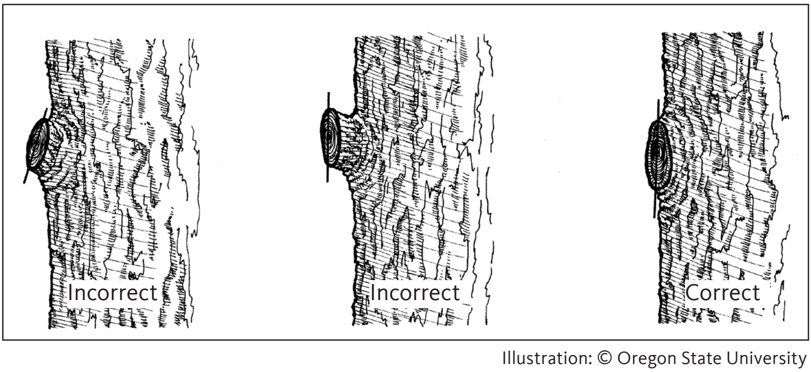

Illustration: © Oregon State University

Figure 7-5. Prune branches properly to minimize damage to the branch collar and subsequent decay. Branches cut at an angle or away from the branch collar (short stub) may result in stem decay. Cut branches close to but not including the branch collar. Flush cuts that remove the branch collar also may result in stem decay.

- Pruning might attract pitch moths; thus, prune in late fall and winter (see Chapter 5, page 64)
- Sunscald may appear on thin-barked species when lower branches are removed.
- Epicormic branches may form, which can form knots that degrade timber value.

For proper pruning, prune branches flush with the branch collar, not flush with the stem (Figure 7-5, page 89). Stubs beyond the branch collar, both on living and dead branches, can allow decay fungi to enter. After pruning, do not paint cuts; wound dressings have been shown to increase decay in some cases.

Chemical and biological controls

Most work on chemical and biological control of stem decays has focused on reducing the effects of tree wounds. No measures have been found to prevent tree decay, although some may promote wound sealing. Wounds lead to wood decay, and after decay begins in a living tree, there is no economical way to stop it with chemical or biological wound dressings.

Fertilizing with urea often improves tree growth and vigor. This may shorten rotations and decrease decay volumes by increasing sound wood volumes. Although wound closure and cross-sectional area of decay are not affected by fertilizing, the percentage of decay is significantly less in trees that have been both thinned and fertilized (Figure 7-3, page 86).

Creating snags and live decayed trees

Dead trees decay from the outside in and provide habitat for a variety of wildlife. Cavity-nesting birds require decay in living trees. The following methods can be used to increase wood decay.

Creating snags (dead trees)

Climb the tree to the base of the crown. Using a chain saw or explosives, top (cut) trees just below the live crown. This rapidly kills the tree and allows many species of airborne fungi to begin the decay process. Trees girdled at the base near the ground tend to fall more quickly than topped trees.

Altering live trees

Climb the tree to halfway into the crown. Using a chainsaw or explosives, sever the trunk; leave part of the crown as a platform about 1 foot in diameter, or attach a wooden platform. This allows the tree to retain live branches for wildlife cover and provides a platform on the trunk for large birds.

Climb the tree to at least 25 feet above the ground and make hollows or slits with a chain saw. Several bird and mammal species use cavities for nesting or roosting.

Wounding live trees

Drill holes into the trunk wood of live trees to become infected with airborne spores of decay fungi (Figure 7-6). Internal decay makes it easier for woodpeckers to create cavities. Live trees with decay stand longer than dead trees.

Climb the tree to at least 25 feet above the ground. Cavities need to be well above the ground to discourage predators. Using a hand drill and bit, drill two or three holes 1 inch in diameter and at least 6 inches deep into the wood. Deep holes allow decay fungi spores to penetrate the heartwood.

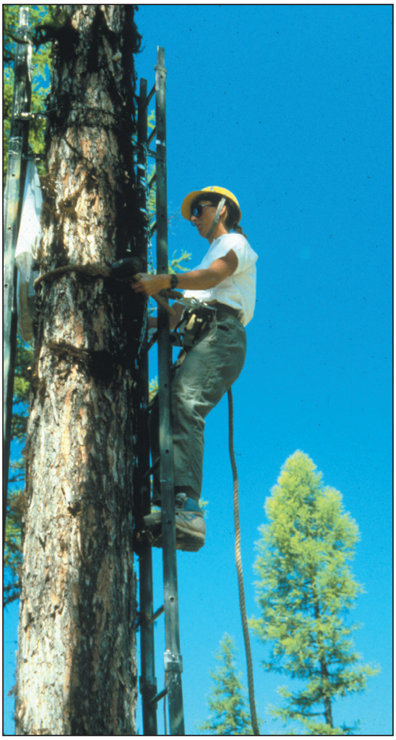

Photo: Greg Filip, U.S. Forest Service

Figure 7-6. Creating woodpecker habitat in a living larch by deeply wounding the tree with a drill, at 25 feet above the ground.

Halfway into each hole, place a piece of plastic pipe 6 inches long and 0.75 inch in internal diameter. Holes in live trees normally seal with pitch or callusing. The pipe forces the hole to remain open for several years to allow air exchange for fungal growth. The holes are easier to see and monitor with the plastic pipe. Stem decay and subsequent wildlife use will take at least 3 years.

Photo: Oregon State University

A researcher conducts a forest survey.

CHAPTER 8

Foliage Diseases[9]

Foliage diseases are caused by various fungi with inconspicuous fruiting bodies, including rust fungi. Some pathogens infect both leaves and stems, making classification as a leaf disease, a shoot blight, or a canker difficult. For example, several rust diseases cause branch brooms, and Diplodia blight of pines also causes cankers. Needle casts are those diseases that result in early leaf loss; in needle blights, the dead or partially dead needles often remain attached to the twig.

Photo: Dave Shaw, © Oregon State University

Figure 8-1. A “lion’s tail” effect is one symptom of foliage diseases in pines.

All conifers are affected by needle diseases to some extent, but in Oregon, they rarely kill trees outright, and relatively few cause major damage or impact (Table 8-1, page 95). Those that do are:

- Douglas-fir—Rhabdocline needle cast and Swiss needle cast
- Larch—larch needle cast and larch needle blight
- Pines—several needle diseases, the most important of which may be Dothistroma needle blight, Elytroderma needle blight, and Bynum’s blight

True firs, hemlocks, spruces, and cedars also have foliage diseases, but usually they are important only in local areas, such as wet draws and valley bottoms, or during certain years when weather conditions allow the fungi to flourish.

Crown symptoms of foliage diseases may include one or all of these:

- Thin crown
- Yellowish crown
- A scorched look in the crown, resulting from reddening of the foliage
- Loss of foliage mostly in the inner and lower crown
- Missing needles within certain age classes of foliage
- A “lion’s tail” effect (Figure 8-1, page 93), especially in pines; i.e.,

[9] Goheen & Wilhite, 202–227

throughout the crown, the needles are concentrated at the ends of the branches

Needle diseases are directly influenced by seasonal weather patterns. Spores of needle-disease fungi spread by air or splashing rainwater. Typically, spread is during a certain period of the year when weather conditions are ideal and when foliage can be infected most easily. Moist spring and summer weather often favors disease initiation. Many foliage diseases also intensify during wet weather; therefore, wet weather that persists into and through summer can increase impacts.

Text continues on page 98

Photo: Alan Dennis, © Oregon State University

A towering stand of fir trees in McDonald Forest.

Table 8-1. Major foliage diseases of Oregon: Hosts, key identifiers, and distribution.

Disease	Hosts	Key identifiers	Distribution
Cedar leaf blight *Didymascella thujina* (= *Keithia thujina*)	Western redcedar	▪ Newer foliage splotchy reddish or bleached in spring, especially lower crown foliage ▪ Brown to black spots on upper side of foliage in summer	Where western redcedar grows, especially west of Cascades
Dothistroma needle blight (red band needle blight) *Mycosphaerella pini*	All pines, especially ponderosa pine, KMX, western white pine, lodgepole pine, knobcone pine	▪ Reddish-brown bands on both sides of foliage, followed by partially dead foliage tips and whole-needle mortality ▪ "Lion's tail" foliage at ends of twigs due to needle loss in previous years	All Oregon; often associated with summer rain
Elytroderma needle blight *Elytroderma deformans*	Ponderosa and Jeffrey pines	▪ Small brooms with dead foliage ▪ Dead spots in inner bark of infected twigs (visible when bark is cut open) ▪ Long dark spots on either side of needles	Eastern Oregon; occasional in southwest Oregon
Fir broom rust *Melampsorella caryophyllacearum*	True firs	▪ Dense, yellowish brooms without dwarf mistletoe ▪ Yellowish spores on needles in spring	All Oregon Pathogen needs alternate host (chickweeds: *Cerastium* and *Stellaria* spp.).
Fir needle cast *Lirula abietis-concoloris*	True firs	▪ Needle browning followed by needle loss, especially in lower crown ▪ Long, black fruiting bodies on undersides of needles	All Oregon; locally common in certain regions

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Table 8-1. (continued) Major foliage diseases of Oregon: Hosts, key identifiers, and distribution.

Disease	Hosts	Key identifiers	Distribution
Incense-cedar rust *Gymnosporangium libocedri*	Incense-cedar	▪ Brooms of dense foliage ▪ Orange-red, gelatinous goo on foliage in spring, which dries to yellow-orange spots	Where host grows, especially southwest and Willamette Valley Pathogen requires alternate host in rose family, such as serviceberry.
Larch needle blight *Hypodermella laricis*	Western larch	▪ Crown may appear to be losing its foliage in early summer rather than in fall. ▪ Dead foliage retained on tree ▪ Black spots on underside of foliage	Eastern and northeast Oregon
Larch needle cast *Meria laricis*	Western larch	▪ Reddish cast to crown in spring and early summer ▪ Red banding on both sides of foliage ▪ Early foliage loss, especially in interior and lower crown	Eastern and northeast Oregon
Lophodermella needle diseases of pine			
Bynum's blight *Lophodermella morbida*	Ponderosa pine, knobcone pine	▪ Reddish crown ▪ Dead foliage concentrated in the interior and lower crown ▪ Small dead spots on either side of foliage (fruiting bodies of fungus) ▪ "Lion's tails" on twigs	Western Oregon

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Table 8-1. (continued) Major foliage diseases of Oregon: Hosts, key identifiers, and distribution.

Disease	Hosts	Key identifiers	Distribution
Lodgepole pine needle cast *Lophodermella concolor*	Lodgepole pine	▪ Reddish crown ▪ Dead foliage concentrated in the interior and lower crown ▪ Small, dead spots on either side of foliage (fruiting bodies of fungus) ▪ "Lion's tails" on twigs	Eastern Oregon
Needle rusts *Pucciniastrum geoppertianum*, *P. epilobii*, *Naohidemyces vaccinii*	True firs, western hemlock	▪ Scattered, often single, dead, yellow needles in crown ▪ Small, hanging, whitish spore pustules on undersides of needles, followed by scattered needle loss	All Oregon; locally common Pathogens need alternate host.
Rhabdocline needle cast *Rhabdocline pseudotsugae*, *R. weirii*	Douglas-fir	▪ Reddish to purplish splotching on needle, with eruptions from splotches ▪ Loss of needles; sparse crowns	All Oregon; on westside, associated with off-site planting; on eastside, associated with wet spring weather, humid locations
Swiss needle cast *Phaeocryptopus gaeumannii*	Douglas-fir	▪ Thin, yellowish crowns; poor foliage retention ▪ Small black dots on underside of needle; needle may look sooty	Mostly western Oregon, in very humid landscapes; epidemic in coastal Oregon

General management of foliage diseases

The first step in managing foliage diseases is to be sure your trees are the appropriate species and seed source for the types of sites on which they will be, or are, growing. In addition, foliage diseases have been historically important in certain areas such as the lower slopes of a mountain range or along the coast. In areas where disease has been a problem in the past, management should take into account the high probability that foliage diseases will be a recurring issue on certain tree species in the future as well.

Off-site planting

Foliage diseases often affect off-site plantings, that is, plantings of trees that originated outside that species' native range or at the margins of its acceptable habitat. Off-site trees can be heavily affected by foliage diseases that would not affect locally adapted trees of the same species. An example is planting ponderosa pine from Wyoming on a site in the Willamette Valley (Figure 8-2). Another example is in Douglas-fir, which commonly was impacted with Rhabdocline needle cast when seed from Washington was used in coastal Oregon. Using the principles of seed zones to select appropriate planting stock for a site has reduced the incidence of Rhabdocline needle cast in Douglas-fir and can be important for preventing diseases in other tree species as well.

Photo: Dave Shaw, © Oregon State University

Figure 8-2. Ponderosa pine from Wyoming, planted in western Oregon (i.e., an off-site tree). Several foliage diseases are making life difficult for this tree.

Air flow and drying

Leaf wetness is a major factor in needle infections. Typical needle diseases are associated with the lower and inner crown; if weather allows, the disease spreads out and up the tree. Thus, the primary technique for managing foliage diseases is to promote air flow that dries the canopy by (a) controlling competing vegetation and (b) maintaining good tree spacing.

However, thinning and vegetation management have not been effective in reducing the severity of Swiss needle cast along the Oregon coast where the disease does best in the upper, warmer, sunny portion of the crown. This may be because, in that region, humidity is high during the spring and summer and moisture may not be limiting.

Fungicides

Fungicides should be a last resort for operational forestry because the underlying reasons for foliage disease problems are usually site selection or off-site planting. Controlling needle diseases with fungicides focuses on preventing infection because once a leaf is infected, fungicides are no longer effective. Fungicide applications must be timed to spore dispersal.

Though several fungicides work against needle disease, they are rarely used in forest operations in Oregon due to their expense and environmental impacts. They are commonly used in Christmas tree farms.

Well-timed and well-directed fungicide applications are known to be effective in younger stands without complex, overlapping crowns. See the current edition of the *Pacific Northwest Plant Disease Management Handbook*, revised annually, for registered chemical controls. Table 8-2 shows whether chemical control treatments were registered in 2017 for common foliage diseases.

Table 8-2. Availability of registered chemical controls for certain common foliage diseases of conifers.

Pest or disease	Registered control?
Cedar leaf blight	Yes
Dothistroma needle blight (red-band needle blight)	Yes
Elytroderma needle blight	No
Fir broom rust	No
Fir needle cast	No
Incense-cedar rust	Yes
Larch needle blight	No
Larch needle cast	No
Pine needle rusts	Yes
Pine needle casts	
Cyclaneusma needle cast	Yes
Lophodermella needle cast	Yes
Lophodermium needle cast	Yes
Medusa needle blight	No
Rhabdocline needle cast	Yes
Swiss needle cast	Yes

Source: *Pacific Northwest Plant Disease Management Handbook*, 2017 edition.

Note: Registrations may change or be withdrawn.

Fertilizers

Fertilizer, especially nitrogen, has mixed associations with foliage disease. One body of evidence suggests high-nitrogen foliage has worse foliage disease and needle loss; examples often cited are of needle diseases in Europe associated with nitrogen deposited by pollution. Other evidence suggests anything that improves tree growth will reduce stress and improve tree health. In general, the relationship between fertilization and foliage disease is unknown.

Management strategies for specific foliage diseases

Cedar leaf blight

Western redcedar may be affected by cedar leaf blight, which can kill foliage and cause loss of lower and inner crown branches. The disease is associated with high humidity, especially in dense stands and shaded understory trees. It tends to flare up after wet spring or summer weather. Manage the disease by improving crown drying, thinning, and keeping crowns well separated.

Dothistroma needle blight (red band needle blight)

One disease does stand out as potentially detrimental to pines—Dothistroma needle blight, also called red band needle blight. This is an important disease of pines grown outside their native range; for example, Monterey (radiata) pine grown in Australia and New Zealand.

In Oregon, it is most common on non-native pines and on cultivars such as the KMX hybrid of Monterey pine and knobcone pine; the Willamette Valley race of ponderosa pine also is susceptible. Moist microsites east of the Cascades may be more prone to the disease (Figure 8-3).

A large epidemic in lodgepole pine caused by Dothistroma needle blight emerged recently in northern British Columbia. The epidemic has been associated with summer rain, which has increased in duration and amount over the past 30 years. The disease could flare up elsewhere, too, if weather patterns allow.

Manage the disease by culling susceptible individuals from plantations and landscapes and by using local seed sources.

Elytroderma needle blight

Elytroderma needle blight of ponderosa pine and Jeffrey pine is an important foliage and stem disease for both species. It may cause witches’ brooms as well as tip dieback and early death of foliage. It is most damaging where humidity is consistently high, such as along creeks and lakeshores and in valley bottoms where fog collects. It is most severe in younger trees and small trees with poor crowns. It’s not known

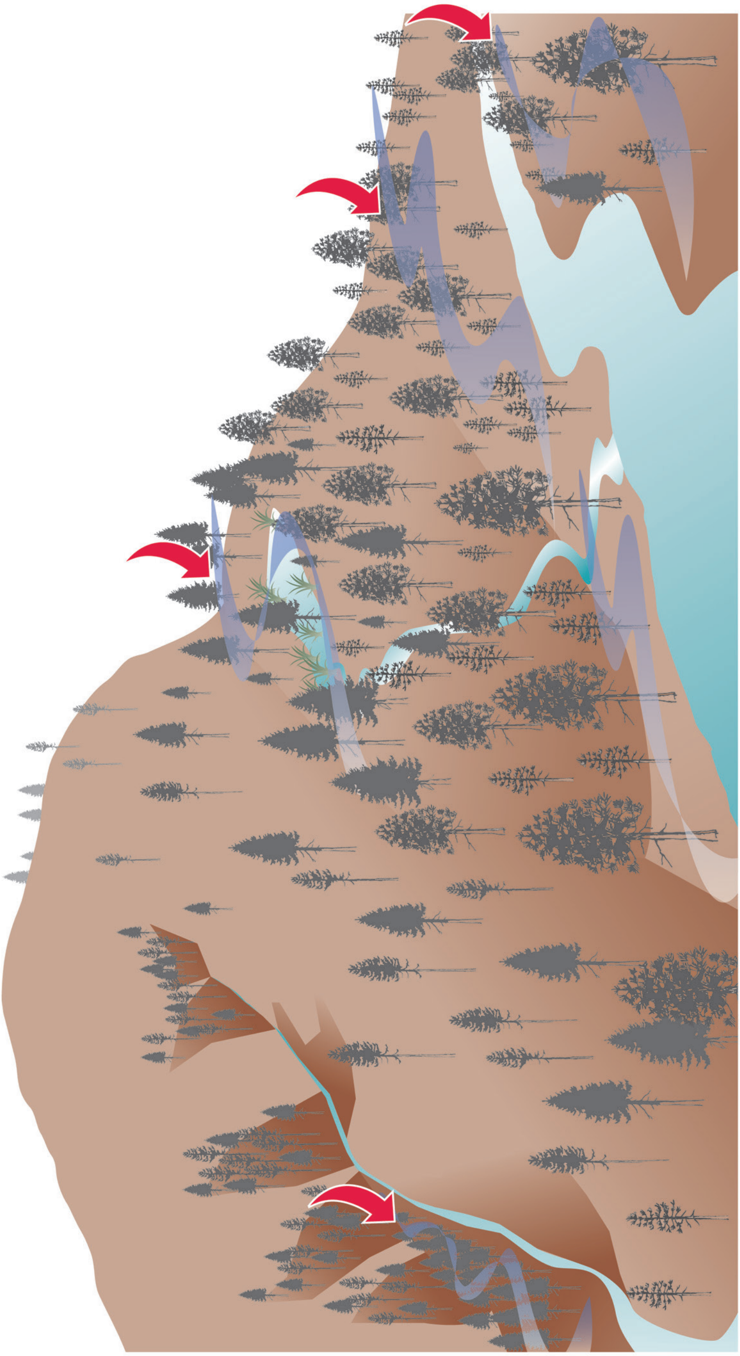

Illustration: Gretchen Bracher

Figure 8-3. Landscape setting and hazard areas for white pine blister rust and foliage diseases. Arrows indicate direction of cold-air drainage and flow of more humid air. Fog indicates where very humid air settles on the landscape.

whether the disease measurably affects tree growth, but if a majority of branches show brooms and dieback, pruning the brooms most likely is the best practice.

Needle rusts and fir broom rust

Fir and hemlock needle rusts are caused by several rust fungi with a variety of alternate hosts, including ferns, huckleberry, and fireweed. Typically, management for these diseases is not needed, but in some instances mowing or controlling vegetation in a plantation will help combat needle loss. One example is grand fir and bracken fern, which share a rust fungus. Mowing bracken may help reduce disease in a high-value plantation or Christmas tree farm.

Fir broom rust causes a witches' broom on the host fir but is rarely a management concern. These brooms will develop discolored foliage, and the needles will have copious spore-producing structures. The alternate host is chickweed (*Cerastium* spp.).

Fir needle cast

Fir needle cast can be important in true firs in local areas; it is especially common in grand fir and white fir wherever they grow. Individual age classes of foliage may be infected throughout the tree crown, although the effect usually is most common on the lower, inner crown area. Trees can look scorched. The disease is associated with high humidity and seasonal weather patterns such as wet spring and summer months. Manage the disease by promoting drying in the canopy.

Incense-cedar rust

Incense-cedar rust is a locally important disease that may result in brooming of twigs and foliage and may cause foliage loss. Increases in disease are associated with wet spring weather. Alternate hosts include shrubs in the rose family such as serviceberry, hawthorne, pear, and apple. The disease may be more significant on commercial fruit hosts. Managing the disease is difficult where alternate hosts are abundant; however, keeping crowns open to dry the canopy should help.

Larch needle blight and needle cast

Larch needle cast and larch needle blight are common in western larch but often are misdiagnosed as larch casebearer feeding damage (see Chapter 3, page 43). Typically, needle cast and needle blight of larch are most important if spring and summer weather is cool and moist for several years. Trees on mountainous sites where fog or clouds accumulate also are susceptible. Manage larch needle diseases through appropriate site choice and planting-stock provenance and by maintaining open canopies in younger plantations.

Lophodermella diseases of pine: Bynum's blight and lodgepole pine needle cast

Bynum's blight, caused by *Lophodermella morbida*, is the most significant foliage disease of ponderosa pine west of the Cascades in Oregon. The disease is associated with off-site seed sources and wet spring and summer weather.

Lophodermella needle cast of lodgepole pine can be significant in local areas. It often flares up after extended warm, wet spring weather in eastern Oregon, especially in the Blue Mountains. If so, take steps to promote drying in the canopy, such as reducing stand density.

Rhabdocline needle cast

Rhabdocline needle cast typically is a disease of younger plantation trees that experience unusually wet spring and summer months, especially several years in a row. Flare-ups typically subside when weather returns to dry summers.

In eastern Oregon, Rhabdocline is a disease of moist sites and prolonged wet spring or summer weather. In western Oregon, Rhabdocline is a disease of off-site planting stock. Therefore, in eastern Oregon, manage Rhabdocline by following typical foliage-disease management. In western Oregon, young stands chronically damaged by Rhabdocline needle cast usually indicate off-site planting stock; it may be best to cull the stand and replant with trees known to be from a local seed source.

Swiss needle cast

In Oregon, Swiss needle cast (SNC) currently is the most economically damaging foliage disease. It is epidemic along the coast, where Douglas-fir grows in the humid, warm, coastal western hemlock–Sitka spruce zone (Figure 8-4, page 104). Fortunately, the disease does not often kill Douglas-fir, but it can significantly reduce its growth and productivity.

Managing Swiss needle cast is difficult in the epidemic zone. The Swiss Needle Cast Cooperative has developed a set of guidelines for the zone, within about 25 miles of the coast.

Assessing and managing Swiss needle cast

1. Assess site hazard

Assess the hazard potential of a site by consulting aerial survey maps (Figure 8-4, page 104) to find the location of your land. Get data at any of these websites:

- Swiss Needle Cast Cooperative http://sncc.forestry.oregonstate.edu/

- Oregon Department of Forestry http://www.oregon.gov/ODF/ForestBenefits/Pages/ForestHealth.aspx
- U.S. Forest Service http://www.fs.fed.us/r6/nr/fid/data.shtml

If your land is in the map area where visible symptoms have been noted over multiple years, there is the potential for impacts from SNC.

2. Assess foliage retention and growth of Douglas-fir trees.

- Assess foliage retention; see Figure 8-5 (page 106) and "Foliage retention" (page 105). Determine tree growth by using an increment core and measuring the number of rings per inch.
- Take into account the density of the trees. Overstocked stands will show reduced growth.
- Take actions for SNC management only if needle retention is low and growth is being impacted. A professional forester can help you assess whether growth is being affected by disease or stand density.

3. Base management on geographic location and evidence of impacts.

The primary environmental controls on disease are (a) temperatures in December through February and (b) spring and early summer leaf wetness (from rain, drizzle, and fog). Some areas near the coast at low elevation and on south slopes show the greatest impacts. Landscape features also appear to influence disease. Base any management decisions on concrete evidence of impacts.

4. Choose appropriate silvicultural techniques.

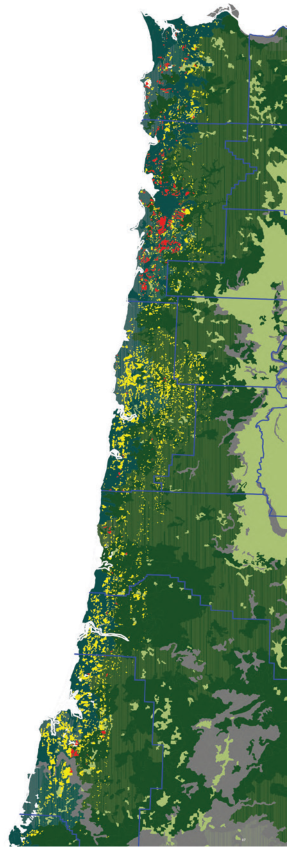

Illustration: Oregon Department of Forestry

Figure 8-4. Aerial surveys in 2016 of coastal Oregon detected more than 546,243 acres of Douglas-fir trees visibly infected areas (red = heavy and yellow = moderate) by Swiss needle cast disease. Note that the problem seems concentrated along the coast and up to about 20 miles inland.

Management strategies

Mixed-species management. The more severe the disease, the less Douglas-fir should be used in a plantation. In some locations, Douglas-fir should not be planted or be favored during thinning; western hemlock, western redcedar, Sitka spruce, and red alder may be better choices there. Where disease is less severe, plant only part of the plantation with Douglas-fir. Favor only healthy-looking Douglas-fir trees when thinning.

Thinning. Precommercial and commercial thinning do not increase or decrease disease impacts. However, thinning early and choosing winners (healthier crown trees) is recommended. It may make sense to favor alternative species to Douglas-fir if disease is severe. In some coastal regions we recommend choosing smaller western hemlock over larger Douglas-fir because they will outperform them. When leaving Douglas-fir, always favor trees with healthy crowns.

Fertilizing. The impact of fertilizer, especially nitrogen, is not understood currently, but because nitrogen is abundant in near-coast soils, nitrogen fertilization is not recommended.

Fungicides. Fungicides are not recommended. Although they work, one application is required annually, and the economic and environmental costs may be too high.

Pruning. Pruning removes the lower branches, but in young Douglas-fir plantations on the coast, SNC is causing foliage loss in the upper crown. Therefore, pruning is not recommended in SNC-impacted stands because it is imperative to leave as much foliage on the tree as possible.

Rotation length. There are no operational guidelines for choosing a specific rotation age. Landowners must balance the economics of longer vs. shorter rotations based on severity of disease and growth impacts.

Foliage retention

The main effect of foliage diseases is loss of productive leaves. The term “foliage retention” describes the amount (in years) of foliage on a conifer tree branchlet. Conifers such as Douglas-fir produce a new cohort of foliage each year, which may stay with the tree for many years, depending on site and elevation. In general, you most likely do not have an economic problem with foliage disease—even if there is evidence of disease—as long as trees retain about 3 years of foliage (Figure 8-5). For example, we estimate about 30 percent growth losses at 2.0 years of needle retention.

A simple way to gauge the years of foliage retained in your trees is to look, with binoculars, at the midcrown area on the sunny side (usually, the south side) of the tree and count the foliage cohorts there. It is best to count cohorts on the laterals rather than on the apical leader of the branch. Take several counts in this area of the tree and average them.

Photos: Alan Kanaskie, Oregon Department of Forestry

Figure 8-5. Counting needle retention on your tree. Douglas-fir, true firs, spruces, and pines have determinate growth, and therefore show distinct cohorts of foliage. At left, a healthy Douglas-fir branch with more than 3 years of foliage. At right, Douglas-fir branchlets with only 1 year of foliage due to Swiss needle cast.

Young stands (10 to 30 years old) appear to be the most impacted stands, although older stands may show severe impacts also, depending on location. For example, several 80-year-old stands in the Tillamook area show heavy impacts, but other stands of similar age in less-severely diseased areas show little impact or no impacts at all. Rotation length should depend on specific landowner needs and plans and on specific stand conditions.

Silvicultural practices for managing major problem foliage diseases in Oregon

- *Make sure the right tree is matched to the site.*
  - ❑ *Stay within seed zone.*
  - ❑ *Avoid off-site planting.*
- *Keep plantations reasonably open to allow air flow to dry the canopy.*
- *Favor mixed species (alternative species) in problem areas.*
- *Avoid planting extensive acreage (entire drainages and watersheds) with young trees of a single species.*
- *Mow or control competing vegetation in young plantations.*
- *Fungicides may be available but are costly and may not be effective in complex, uneven crowns of trees 20 years old and older. They may be most effective in young (10 to 20 years), simple-crown trees that are going through a key development period.*
- *Fertilizer, especially nitrogen, may increase foliage disease, but the relationship is still ambiguous and probably is site specific.*

Chapter 9

Canker Diseases and Canker-Causing Rust Diseases[10]

Cankers are localized, dead areas of bark on a tree's branch or trunk. These range from small, sunken areas of bark where the cambium recently died to large, callused areas surrounding exposed wood. A canker can be caused by many factors, but fungi are common agents. Cankers caused by fungi can be annual or perennial. Two groups of fungi cause cankers: rust fungi and nonrust fungi (Table 9-1, page 109).

Canker-causing rust diseases

Rust fungi are specialized, parasitic fungi that live on leaves, stems, and trunks where they cause branch and bole cankers and foliage diseases. Some of these fungi cause galls (swollen, woody, deformed structures) on branches and the main trunk. The blister rusts cause blistering cankers that seasonally produce white, yellow, or orange spore masses and often produce an ooze. Rodents and squirrels are attracted to the blisters, where they nibble away the bark.

Most conifer rust fungi have complex life cycles that require both a conifer host and a leafy host, called an alternate host. However, some fungi do not require alternate hosts.

Whether hosts are infected by rust fungi depends on the timing of fungal spore release and on the weather pattern at that time. Very dry, hot weather is not conducive to infection by these fungi. During certain years, when weather is favorable for the fungus, many infections may occur. This phenomenon is called a "wave year." These usually are years when weather is especially moist and cool (but not cold) while conifer hosts are being exposed to infection.

Management recommendations for canker rusts are summarized in Table 9-2, page 112.

White pine blister rust

White pine blister rust—a non-native rust of five-needle pines—is the most important forest rust in Oregon because it almost always kills the tree. The rust has caused a major decline of many of its host trees, which include western white pine, sugar pine, and whitebark pine. This rust invades leaves through their air pores (stomates) and grows through the leaves into the branchlet and branch, where the fungus causes an expanding canker that eventually can invade the main stem and girdle the tree.

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[10] Goheen & Willhite, 120–139

White pine blister rust requires an alternate host to complete its life cycle. Alternate hosts primarily are shrubs in the *Ribes* (currant) group, in which the fungus causes a foliage disease. **There is no pine-to-pine infection in this disease.** It moves from pines to *Ribes* bushes in spring and then back to pines in fall. Therefore, controlling the distribution of currant bushes within 0.5 mile of pines has been thought to help control the disease. However, large-scale eradication of *Ribes* was attempted for several decades in the 1900s but was unsuccessful.

Photo: Chris Schnepf, © University of Idaho

Figure 9-1. Pruning western white pine removes foliage from the high-humidity zone where white pine blister rust infection is most common.

Table 9-1. Common canker-causing diseases in Oregon: Hosts, key identifiers, and distribution.

Disease	Hosts	Key identifiers	Distribution
Canker-causing rust diseases			
White pine blister rust *Cronartium ribicola*	Five-needle pines—western white pine, sugar pine, whitebark pine	▪ Branch flagging ▪ Top dieback ▪ Canker on branch and stem; seasonal spore mass ▪ Resin flow ▪ Rodent nibbles ▪ Mortality	All Oregon. Pathogen requires alternate host: currant (*Ribes*) but also paintbrush (*Castelleja*) and lousewort (*Pedicularis*) are possible alternate hosts.
Comandra blister rust *Cronartium comandrae*	"Hard" pines—ponderosa pine, lodgepole pine	In large trees— ▪ Progressive top dieback ▪ Heavy resin at margin of dead area and in wood In small trees— ▪ Bole and branch cankers; mortality	Especially central Oregon and east of Cascades. Pathogen requires alternate host: bastard toadflax (*Comandra*).
Stalactiform rust *Cronartium coleosporioides*	Lodgepole pine	In young trees— ▪ Spindle-shaped swelling ▪ Large, diamond-shaped canker on bole can kill small trees.	East of the Cascades, especially Oregon Plateau in south-central Oregon. Pathogen requires alternate host: chickweeds (*Cerastium*, *Stellaria*).
Western gall rust *Endocronartium harknessii* (= *Peridermium harknessii*)	"Hard" pines— lodgepole pine, ponderosa pine, knobcone pine, Monterey x knobcone pine (KMX)	▪ Swollen, woody gall ▪ Hip cankers ▪ Trees broken at swelling ▪ Branch flagging	East of the Cascades, Blue and Wallowa mountains, southwest Oregon, Willamette Valley. Does not require an alternate host.

Continued on next page

Table 9-1. (continued) Common canker-causing diseases in Oregon: Hosts, key identifiers, and distribution.

Disease	Hosts	Key identifiers	Distribution
Canker diseases caused by other fungi			
Atropellis canker of pines *Atropellis piniphila*, *A. pinicola*	Lodgepole pine, sugar pine, western white pine, ponderosa pine	▪ Long, vertical, perennial cankers ▪ Resin ▪ Blue-black stain of wood	East of the Cascades, Blue and Wallowa mountains, southwest Oregon
Diplodia (Sphaeropsis) tip blight and canker *Diplodia pinea* (=*Sphaeropsis sapinea*)	Pines; occasionally other species of conifer	▪ Branch flagging ▪ Tip dieback ▪ Top kill ▪ Mortality rare	East of the Cascades, Blue and Wallowa mountains, southwest Oregon, Willamette Valley
Annual cankers of conifers caused by various fungi *Cytospora* spp., *Phomopsis* spp., *Diaporthe* spp., *Dermea* spp., *Grovesiella* spp.	Douglas-fir, true firs, incense-cedar, western larch	▪ Branch flagging ▪ Sunken, dead areas on young bark ▪ Top and branch dieback ▪ Associated with bark and twig beetles	All Oregon, especially Willamette Valley and southwest Oregon Phomopsis is especially important in southwest Oregon Douglas-fir.

From an ecosystem viewpoint, the failure might be considered a good thing, because *Ribes* are native plants, important to wildlife in Oregon. Recently, it has been reported that plants in the genera *Castilleja* (Indian paintbrush) and *Pedicularis* (lousewort) are also alternate hosts. Although the relationship to these other alternate hosts is poorly understood, eradication of *Ribes* bushes seems all the more futile for controlling the disease in the West.

Management strategies

The primary management for white pine blister rust in western white pine and sugar pine plantations is to:

- Plant stock that is confirmed to be genetically resistant.
- Prune early in the life of the plantation (Figure 9-1, page 108).

Reducing competing vegetation around the lower crown, to increase drying of the foliage, has been recommended but is untested.

Pruning. Pruning removes foliage in the humid zone, near the ground and understory vegetation, and so reduces fungal spore infection on leaves. Spores from *Ribes* bushes, or other alternate hosts, must land on the pine needle, germinate, and grow into the needle's stomates (air pores). The spores' highest success is on moist needles, and at this early stage in the infection cycle, spores are susceptible to drying.

Prune no higher than 50 percent of tree height. The maximum height needed to reduce rust infections is thought to be 8 to 10 feet above the ground, but this is not documented for Oregon. For details on pruning western white pine for disease resistance, see Schnepf and Schwandt (2006), page 130.

Site selection. Site selection can play a role in managing white pine blister rust. Some sites include spots where air pools and where spores, transported from upslope, can accumulate in the lower, heavier, and more humid air. These sites are usually bottoms and midslope flats and areas around wetlands (Figure 8-3, page 101). Ridgetops in southwest Oregon, especially saddles, are reported to be particularly bad, perhaps due to air-flow patterns.

Table 9-2. Silviculture and tree seed source considerations in managing major problem canker rusts and canker diseases in Oregon.

Disease	Silviculture	Tree seed source
Canker-causing rust diseases		
White pine blister rust (non-native)	▪ Prune lower branches as soon as possible. ▪ Remove bole-infected trees during thinning. Though the science to support this is limited, it may also be advisable to: ▪ Manage vegetation to reduce humidity. ▪ Remove *Ribes* in immediate vicinity of plantation.	Use only improved, rust-resistant seed source.
Comandra blister rust	▪ Avoid plantations in high-hazard areas, especially where the comandra plant is common in shrublands near pine.	Stay in seed zone.
Stalactiform rust	▪ Remove infected trees during thinning.	Stay in seed zone.
Western gall rust	▪ Prune gall-infected branches in high-value stands. ▪ Delay precommercial thinning. ▪ Remove bole-infected trees during thinning. This rust infects pine-to-pine; i.e., a gall on a pine can be the source of spores that infect adjacent pines.	Stay in seed zone. This disease is notorious on off-site pines.
Canker diseases caused by other fungi		
Atropellis canker of pines	Trees are resistant until about age 15. In problem areas: ▪ Remove older infected trees near plantations. ▪ Remove infected trees during thinning.	Stay in seed zone.
Diplodia (Sphaeropsis) tip blight and canker	▪ Avoid stressful sites (droughty and nutrient-poor). ▪ Thin to decrease water stress. ▪ Where these diseases are chronic and severe, use alternative tree species, and prune in winter when spores are fewer. But, pruning may not reduce spore loads because cones can be infected. ▪ Late-summer watering may help individual trees.	Stay in seed zone. This is especially a disease of off-site trees.
Annual cankers of conifers due to various fungi, especially *Phomopsis* in Douglas-fir	Reduce drought stress through: ▪ Thinning ▪ Vegetation management ▪ Late-summer watering ▪ Mulching open-grown trees	Stay in seed zone. Expect problems outside tree's natural range and on marginal sites.

Comandra blister rust

Comandra blister rust on pine (ponderosa and lodgepole pine are primary hosts) causes top dieback on older trees as well as branch flagging and branch and bole cankers on younger trees. The rust rarely kills young trees. The disease is locally severe in Oregon and is especially common in central Oregon on the Deschutes National Forest, where many of the old-growth, "yellow-belly" pines have dead tops and are dying slowly from the top downward. Copious resin in the bark and wood in the dead part of the tree is evidence of the continual battle between fungus and host.

An alternate host, *Comandra umbellata* (bastard toadflax, Figure 9-2), is required to complete the life cycle of the fungus. On *Comandra umbellata*, the fungus causes a foliage disease. In some regions, these comandra plants are limited to certain habitat types, such as grassland–shrub ecosystems too dry for pine. However, where the alternate host is common in shrublands that intermingle with pine, the disease hazard is high.

Photo: William Jacobi, Colorado State University, Bugwood Network

Figure 9-2. This bastard toadflax (*Comandra umbellata*) shows signs of infection by the blister rust fungus.

Research by the US Forest Service indicates that the old-growth trees along a stretch of the Metolius River all were infected during a wave year, or years, in the 1930s when weather conditions were perfect for infection. It has been proposed that large, warm-front rains that carry spores in an optimal environment from comandra plants to pines are needed to create a wave year. Those conditions are rare in that area; after the 1930s, no new infections were seen for 40 years.

Besides comandra blister rust, another cause of top dieback in old pines is *Ips* and other bark beetles (see Chapter 2), but those tree tops die in a single event. The comandra blister rust trees have a progressive decline which is evidenced by the more recently dead branches below older dead branches.

Management strategies

Managing comandra blister rust includes these strategies:

- Prune cankers.

- Thin infected trees during routine operations.
- Control comandra plants near plantations.

Stalactiform rust

Stalactiform rust can cause vertical, diamond-shaped cankers up to 30 feet long on lodgepole pines. Older cankers are resin soaked and yellowish, while younger, active cankers may have a clear ooze and yellow spore masses in early summer.

This rust can kill regeneration in a plantation. In Oregon, it is a management concern mostly on the central Oregon plateau in the summer in dry, lodgepole pine forests. Alternate hosts are members of the plant family Scrophulariaceae, especially paintbrush.

The primary management tool for this disease is to remove infected trees during routine thinning and harvesting operations.

Western gall rust

Western gall rust on lodgepole, knobcone, and ponderosa pines is a common and potentially important rust. Sometimes called a hard pine rust, it also is common on off-site hard pines (Austrian pine) and on the Monterey pine x knobcone pine hybrid known as KMX. Infection is pine-to-pine and does not require an alternate host.

This disease is evident in swollen, woody galls that form at the infection site. The fungus is restricted to the gall. Infection is during branch elongation and only on new tissues. An individual gall usually is not important to the life and productivity of the tree unless it is on the main stem. Then, the tree often does not make it to maturity, because the stem breaks at the gall. Galls and infections can cause branch dieback. The disease builds up in stands during wave years, when the weather is humid during peak spore dispersal and many branch tips are infected.

Management strategies

Management of western gall rust often is not needed. However, the disease can move into a young plantation during wave years in certain areas in eastern Oregon lodgepole pines and in southwest Oregon in ponderosa pines and knobcone pines.

One management suggestion—from Alberta, Canada, where the disease is important—is to allow dense lodgepole pine stands to grow a longer time before precommercial thinning. Trees with main-stem galls can be thinned out after the stand has grown through the stage of highest susceptibility.

If gall rust moves into a high-hazard site during a wave year, manage the stand for mixed species that include a species other than pine.

Pruning individual branches with galls is recommended for high-value plantations.

Almost all stands contain host trees that are apparently more resistant to western gall rust than others in the same stands. In thinnings, discriminate against heavily infected hosts while retaining hosts that exhibit no disease or only light infections.

Canker diseases caused by other fungi

Canker diseases caused by the nonrust fungi are divided into annual and perennial cankers. Perennial cankers can look like a target—the center may be exposed dead wood or tissue surrounded by raised, callused tissue. Some fungi also may cause shoot and twig blights. Nonrust fungi do not require an alternate host; the fungus completes its life cycle on the tree.

Management recommendations for canker diseases caused by nonrust fungi are summarized in Table 9-2, page 112.

Atropellis canker of pines

Atropellis canker is mostly on lodgepole pine in Oregon but is not of major importance. It can cause “target” cankers that appear as fairly large, elongated, flattened depressions with roughened bark; resin flow may be copious. Stems may be contorted in trees that have had a canker for some time, and the wood under the canker will be stained blue-black.

Management of the disease usually is not warranted, but remove trees with obvious trunk cankers during routine thinning and cutting.

Diplodia (Sphaeropsis) tip blight and canker

Diplodia tip blight and canker is a common disease of off-site, drought-stricken, and otherwise weakened pine trees. Sometimes it also affects cedars and other hosts. Though the disease can be devastating, the fungus is considered a weak pathogen that is effective only when another factor already has stressed the tree.

Diplodia can kill needles and twigs, cause branch flagging, and kill the top and even the entire tree. The fungus also infects pine cones, causing them to be smaller than normal and deformed.

In Oregon, the disease can be a management concern in young pine plantations with off-site stock or on especially droughty soils or sites. Recently, the disease has been found on incense-cedar in the Willamette Valley following droughty summers.

Management strategies

Manage Diplodia tip blight and canker with these practices:

- Ensure the right tree is in the right site (Figure 9-3); i.e., use stock from appropriate seed zones.

- Limit stress, especially water stress, by maintaining appropriate stocking levels.

Occasional summer watering may help specimen trees. In areas where the disease is causing problems, plant with alternative species.

Pruning may be advised in winter, when spores are not being dispersed. However, pruning apparently does not reduce spore loads because cones on otherwise uninfected branches also can harbor the disease.

Annual cankers of conifers

Annual cankers usually result when fungi colonize younger bark of stressed trees. Cankers are especially common on off-site trees. Annual cankers are sporadic and are associated with certain weather, for example, drought that stresses trees and hailstorms that damage bark and provide entry for the fungus. Douglas-fir and grand fir in the Willamette Valley and southwest Oregon have more cankers during and after drought.

When canker fungi girdle the tree stem, they can cause branch dieback and flagging. Trees also may become more susceptible to twig beetles and weevils, such as the Douglas-fir twig weevil (see Chapter 5, page 55). Infestation can occur in patches and is associated with edge effect, desiccation, and droughty soils.

Photo: Lynn Ketchum, © Oregon State University

Figure 9-3. Planting the right species of tree, given site characteristics, is a key step in preventing forest diseases.

Management strategies

Manage annual cankers by reducing drought stresses. Reducing competition through vegetation management and lowering tree density is one approach. In extreme cases, mulching young, open-grown trees may help.

Another approach is to plant drought-tolerant species on soils known to be droughty. For example, in many Willamette Valley bottomlands, where soils are wet in winter and droughty in summer, annual cankers often afflict Douglas-fir. The alternative species, Willamette Valley ponderosa pine, is much more appropriate for that type of site.

Chapter 10

Mistletoes[11]

Dwarf mistletoes and leafy mistletoes are parasitic, flowering plants that can retard growth, deform crowns and branches, and eventually kill the trees in which they grow.

Leafy mistletoes are in the genus *Phoradendron*; their seeds are dispersed by birds. A common example is oak mistletoe (*Phoradendron villosum*, not covered in this book) in western Oregon. Some "leafy" mistletoes have reduced, scale-like leaves. Leafy mistletoes affect juniper and incense-cedar but rarely are a management concern (Table 10-1, page 119).

Photo: Dave Shaw, © Oregon State University

Figure 10-1. Dwarf mistletoe has caused witches' brooms in this fir on Mount Hood.

All dwarf mistletoes have reduced, scale-like leaves. Seed is explosively discharged from the plant; it does not require birds for dispersal. Many species of dwarf mistletoe cause the branch on the host tree to form a characteristic witches' broom, in which many branchlets cluster around a swollen stem (Figure 10-1). Twelve types of dwarf mistletoe grow in Oregon; most conifers, except cedars and spruces, are affected in some part of their geographic range (Table 10-1).

Although mistletoes can be bad for an individual tree, there is considerable evidence that they enhance wildlife habitat. The brooms provide nesting and roosting structures, and the negative effects on trees create snags and partially dead tree crowns, which also favor nesting.

Dwarf mistletoe management

The only known direct control of dwarf mistletoes is to prune infected branches or kill the host tree. Biological and chemical controls, and developing genetically resistant stock, have not been used because silviculture and direct control usually can solve the problem. Genetic resistance is effective and could be practical in some situations.

Consider your overall forest management objectives before deciding how to manage dwarf mistletoes. If timber production is your primary goal, then you may need to manage to minimize dwarf mistletoe in

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[11] Goheen & Willhite, 154–167

plantations. However, if your goals include biodiversity and wildlife habitat, then retaining some levels of dwarf mistletoe may be called for.

Managed correctly, low levels of dwarf mistletoe will not significantly affect a forest stand. However, before deciding to leave dwarf mistletoe in a stand, consider that infection could spread—depending on stand composition and structure—to harm more trees.

Dwarf mistletoes spread by shooting seeds up to 50 feet. Each dwarf mistletoe species tends to be rather host specific: i.e., usually each infects, and is severe on, only one species of tree but perhaps lightly infects one or a few others. Seeds disperse most effectively in evenly distributed, well-spaced host crowns, and the mistletoe spreads to understory trees that are the same species as the overstory.

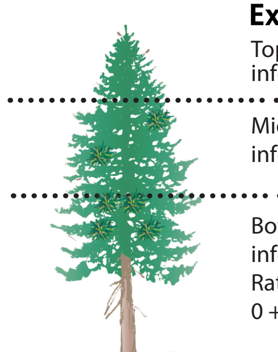
Dwarf mistletoes love light and produce the most robust aerial shoots and best complement of fruit in full sun. Leaving heavily infected trees in a widely spaced overstory, such as a shelterwood, will maximize the spread of dwarf mistletoe to the next generation of trees. However, since dwarf mistletoes are host specific, they may be isolated using nonhost tree species whenever possible.

Dwarf mistletoe severity assessment

Assess dwarf mistletoe severity in the stand before deciding how to manage the infection. A rating system is described in Figure 10-2. Evaluate infection levels (using a 0–6 scale) in a sample of trees throughout the stand and average their ratings. If the average is greater than 3, the stand is severely infected. Typically, stand-level ratings will increase by one level each decade (e.g., from infection level 1 to level 2) without management intervention. The decision to manage dwarf mistletoe should be based on the stand assessment of infection levels and on some understanding of the cost–benefit ratio of possible actions.

Rating system

Step 1. Divide the live crown into thirds.
Step 2. Rate each third as 0, 1 or 2, with 0 = no visible infection, 1 = half or fewer branches infected, and 2 = more than half of the branches infected.
Step 3. Add ratings of each third to get rating for total tree.



Example

Top third has no visible infection. Rating = 0.

Middle third lightly infected. Rating = 1

Bottom third heavily infected. Rating = 2
Rating for tree =
0 + 1 + 2 = 3

Illustration adapted from Hawksworth and Weins

Figure 10-2. Dwarf mistletoe rating (DMR) system.

Table 10-1. Dwarf mistletoes and leafy mistletoes of Oregon conifers: Hosts, key identifiers, and distribution.

Mistletoe	Major host(s)	Key identifiers	Distribution
Dwarf mistletoes of conifers			
Fir dwarf mistletoe *Arceuthobium abietinum* f. sp. *concoloris*	Grand fir, white fir	▪ Moderate-size brooms ▪ Flagging of branches in broom ▪ Associated with cankers ▪ Robust plants	East of Cascades; southwest Oregon.
Red fir dwarf mistletoe *Arceuthobium abietinum* f. sp. *magnificae*	Shasta red fir	▪ Moderate-size brooms ▪ Flagging of branches in broom ▪ Associated with cankers ▪ Robust plants	Southern Cascades at high elevation.
Lodgepole pine dwarf mistletoe *Arceuthobium americanum*	Lodgepole pine	▪ Can have both ⇨ small to moderate size, localized brooms ⇨ large, systemic brooms that can be bigger than a car ▪ Whorled branching pattern	East of Cascades; Blue and Wallowa mountains.
Western dwarf mistletoe *Arceuthobium campylopodum*	Ponderosa pine, Jeffrey pine	▪ Branch swelling ▪ Clumped foliage ▪ Robust plants ▪ With or without brooms ▪ Usually moderate brooming, but branches can grow large	East of Cascades; Blue and Wallowa mountains; southwest Oregon.

Table 10-1. (Continued) Dwarf mistletoes and leafy mistletoes of Oregon conifers: Hosts, key identifiers, and distribution.

Mistletoe	Major host(s)	Key identifiers	Distribution
Whitebark pine dwarf mistletoe *Arceuthobium cyanocarpum*	Whitebark pine	▪ Branch swelling at infection site ▪ Minimal brooming ▪ Conspicuous plants	Single site in central Cascades; not a management concern.
Douglas-fir dwarf mistletoe *Arceuthobium douglasii*	Douglas-fir	▪ Huge brooms ▪ Minute plants among foliage ▪ Host-tree branches in broom remain small	East of Cascades; Blue and Wallowa mountains; southwest Oregon.
Larch dwarf mistletoe *Arceuthobium laricis*	Western larch, mountain hemlock	▪ Dense, moderate-size brooms and plants ▪ Branch swellings	East of Cascades; Blue and Wallowa mountains.
Western white pine dwarf mistletoe *Arceuthobium monticola*	Western white pine	▪ Moderate-size brooms ▪ Branch swelling ▪ Conspicuous plants	Extreme southwest Oregon.
Knobcone pine dwarf mistletoe *Arceuthobium siskiyouense*	Knobcone pine	▪ Brooms ▪ Deformed host-tree crowns	Extreme southwest Oregon.
Mountain hemlock dwarf mistletoe *Arceuthobium tsugense* subsp. *mertensianae*	Mountain hemlock	▪ Dense brooms ▪ Small plants ▪ Swollen host-tree branches	Cascade crest.

Table 10-1. (Continued) Dwarf mistletoes and leafy mistletoes of Oregon conifers: Hosts, key identifiers, and distribution.

Mistletoe	Major host(s)	Key identifiers	Distribution
Western hemlock dwarf mistletoe *Arceuthobium tsugense* subsp. *tsugense*	Western hemlock, Pacific silver fir, noble fir	▪ Moderate-size, dense brooms can completely change host tree structure ▪ Robust plants ▪ Swollen host-tree branches	Western Oregon; east of Cascades where western hemlock grows.
Pacific silver fir dwarf mistletoe *Arceuthobium tsugense* subsp. *amabilae*	Noble fir, Pacific silver fir, subalpine fir, mountain hemlock	▪ Moderate brooming ▪ Swollen host-tree branches ▪ Robust plants ▪ Associated with cankers	Cascade crest; high elevations of the Coast Range.
Leafy mistletoes of conifers			
Incense-cedar mistletoe *Phoradendron libocedri*	Incense-cedar	▪ Robust, evergreen, much bigger than dwarf mistletoes ▪ Minor brooming ▪ Deformed host-tree branches and crowns	Extreme southwest Oregon; southern Cascades.
Juniper mistletoe *Phoradendron juniperinum*	Western juniper	▪ Robust, evergreen plants, much bigger than dwarf mistletoe but with small, scale-like leaves	East-central, central, and southern Oregon.

Dwarf mistletoe characteristics and management implications

Several important aspects of dwarf mistletoe (DM) biology and ecology make the mistletoe amenable to forest management.

DMs are parasites that require a living host. If the tree or branch is dead, so is the DM on it. No management action is needed on dead trees or branches.

DMs are generally host-species specific; that is, a given mistletoe will infect only one or a few species of tree. Mixed-species management will limit the spread and impact of DM. Avoid regeneration of similar species of trees directly next to or under infected trees.

DM plants take time to grow and multiply—usually 4 to 6 years from seed to mature plant. Stand-level infection increases relatively slowly, allowing time to plan and to manage the stand during regular entries.

DMs spread slowly in closed-canopy stands, usually on average about 1 to 2 feet radially per year. However, a single infected tree that stands over regeneration can disperse seed 40 feet or more, and DM can impact a stand substantially over 10 to 20 years. The stand situation drives management decisions; therefore, it's important to know dwarf mistletoe's distribution and potential for spread before making stand entries.

DMs are easy to see, in most cases. Surveying for dwarf mistletoes usually is easy, which makes it easier to decide whether it is a problem. Tree cutters can identify infected trees easily.

DM usually does not affect tree growth measurably or significantly until the tree's infection rating is 4 or higher. No DM management is needed in lightly infected trees unless they are in an overstory above a sunlit understory.

DM distribution tends to be clumped (Figure 10-3). Clumps, also called infection centers, can be isolated by planting or favoring nonhost species. Or, remove clumps by selective harvesting.

DMs require light to produce seed. Light enhances DM shoot and seed production. Thinning, individual tree selection, and small-group selection open the crowns of residual trees to more light and therefore can lead to significant increases in stand infection. Precommercial thinning is recommended on good sites because trees may outgrow the mistletoe; on the other hand, consider delaying commercial thinning if infection is widespread throughout the stand. Maintaining high tree densities is a management strategy that limits DM seed production and spread by fostering shade and limiting seed dispersal distance.

Stand management

The principal way to manage dwarf mistletoes is through stand management. Since dwarf mistletoes spread mainly by explosively discharging seed onto nearby trees (Figure 10-4, page 124), DM tends to form distinct infection centers around the initially infected trees, which often were left after a fire or a cutting. Although birds can carry seed long distances, they are not the primary means of spread. To manage dwarf mistletoes, then, you must manage the spacing of infected trees.

Control at final harvest

The best time to control dwarf mistletoes is at final harvest. Clearcutting, the oldest means of dwarf mistletoe control, eradicates it from the stand by killing all overstory hosts. At harvest, also remove infected advance regeneration taller than 3 feet, and make sure any taller residual trees are not infected. Preventing spread into new plantations then becomes the primary means of managing dwarf mistletoe.

If you use uneven-aged management, green-tree retention, shelterwood, or seed-tree systems, it is important to know whether overstory trees are infected and, if so, their distribution in the stand. Control is best when no trees remain in the overstory to infect the understory. If it's necessary to leave infected trees after shelterwood

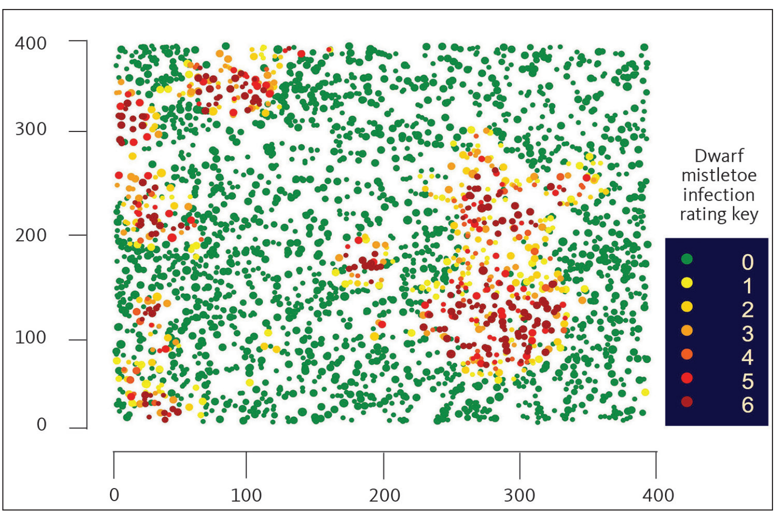


Figure 10-3. Distribution of DM-infected trees in a 30-acre, old-growth stand in the Gifford Pinchot National Forest. Only western hemlock trees are shown, but the infection centers are distinct.

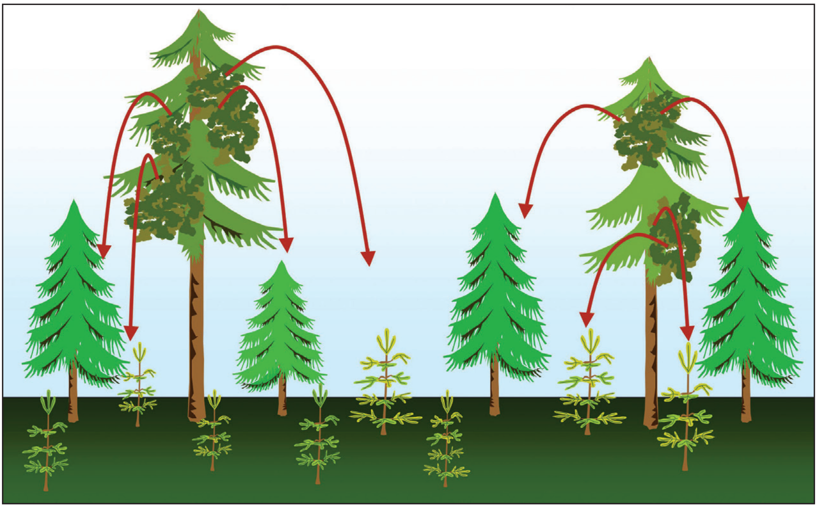


Illustration: Nancy Boriak

Figure 10-4. Dwarf-mistletoe-infected trees in the overstory rain DM seed down on understory trees.

and seed-tree cuttings, remove the infected trees before understory regeneration is 3 feet tall or after 10 years. If infected trees are retained in a stand, it is preferable to select trees with infections in the lower half of the crown, as the seed from the upper half of the crown may disperse farther.

Uneven-aged management is not recommended in moderately to heavily infected, single-species stands of dwarf mistletoe hosts. However, group selection that removes infection centers may be an uneven-aged management approach.

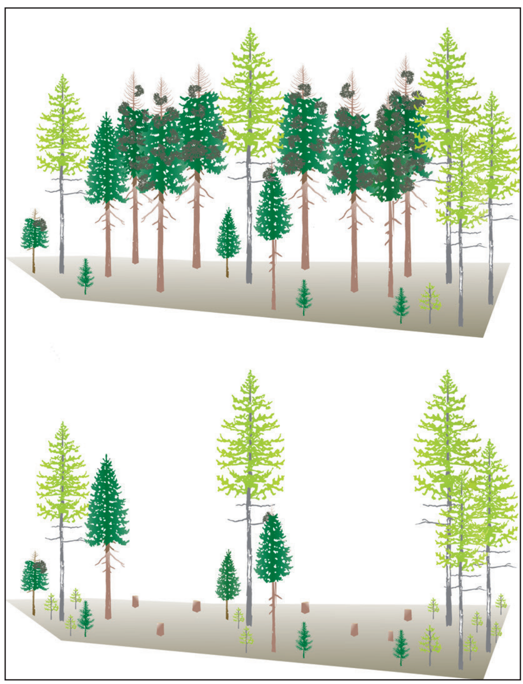


Illustration: Gretchen Bracher

Figure 10-5. Thinning infected trees complements mixed-species management.

Without a DM seed source in the overstory, young infected trees may outgrow dwarf mistletoe infections by shading them out. This is most likely on sites that are moderately productive or better. On poorer sites, which require wide spacing for optimal tree growth, shade is less, and trees may not be able to outgrow dwarf mistletoe.

Control during stand entries

Stand entries are opportunities to control dwarf mistletoes (Figure 10-6). During thinning, remove the most heavily infected trees and favor nonhost tree species. Specific sanitation thinning may be required in some instances (for example, if you're a new owner who has just discovered the problem), but generally it is more economical to control dwarf mistletoe during standard field operations.

Photos: W. T. Adams, © Oregon State University

Figure 10-6. A DM-infected stand (top photo) and management treatment (bottom photo).

Stands may be so heavily infected that removing most infected trees would result in unacceptable stocking levels. In that case, manage dwarf mistletoe by reducing density, isolating the most severe infection centers, and removing heavily infected dominant and codominant trees when opportunity arises.

In mistletoe problem areas, consider using natural or constructed breaks in the landscape—such as roads, streams, meadows, or rock outcrops—to limit the spread of DM back into the stand.

Mixed species management

Mixed-species management is one way to control dwarf mistletoes in both even- and uneven-aged systems. Besides being impervious to infection, nonhosts also can physically block seed spread to susceptible species (Figure 10-7, page 124). Use nonhost species:

- At the margins of clearcuts, when adjacent stands are infected
- In plantings around or under infected overstory trees
- During thinning, to isolate infection centers or heavily infected trees from the remaining stand (Figure 10-5)

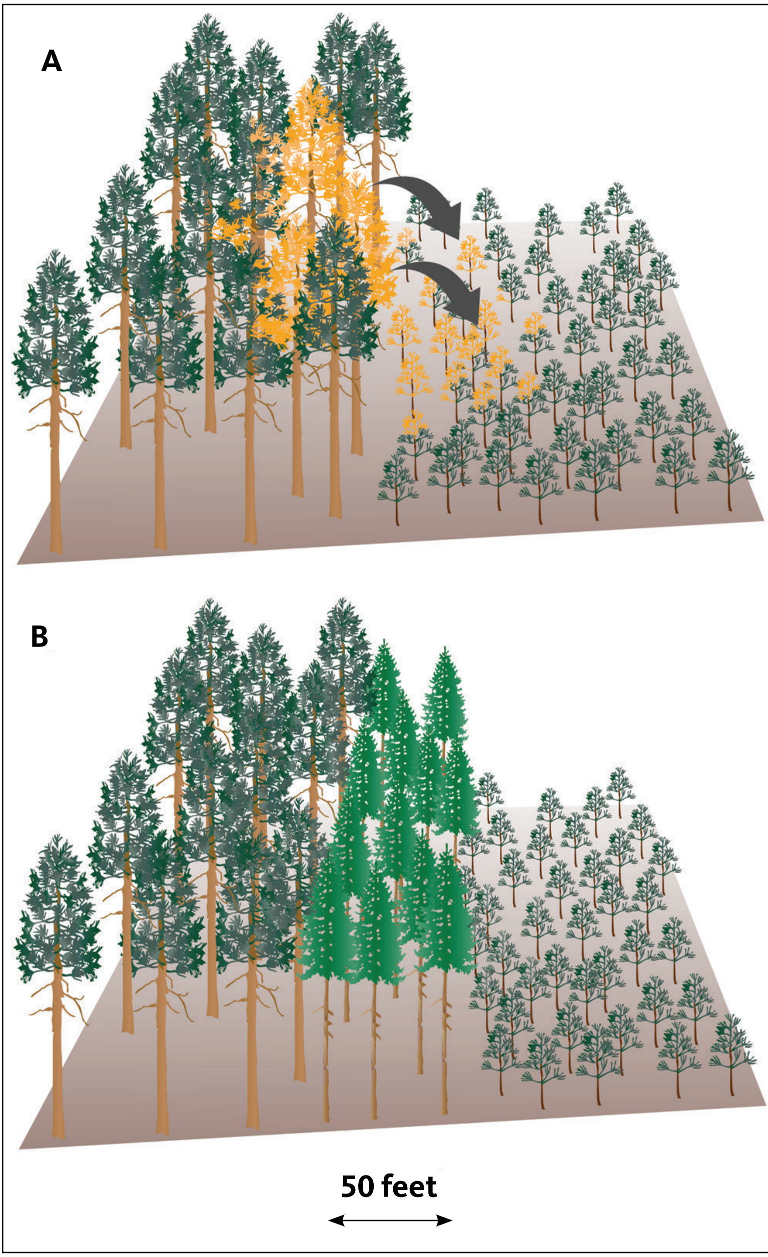


Illustration: Gretchen Bracher

Figure 10-7. To prevent spread of dwarf mistletoe back into the plantation (A), establish a 50-foot buffer of nonhosts (B).

Prescribed fire

Prescribed fire does not eliminate DM from a site, but it may reduce the stand's average infection rate. Low-intensity fires might selectively kill DM-infected trees because they often have excess branching and low-hanging brooms filled with dry leaves. In addition, prescribed fire often kills infected regeneration.

Summary of silvicultural recommendations for dwarf mistletoes

Even-aged management

- During thinning operations, remove heavily infected trees; i.e., with a dwarf mistletoe rating (DMR) of 4 to 6.
- During clearcut harvest, remove infected regeneration.
- If reserves and riparian areas next to plantations have infected trees, prevent spread into the plantation with buffers of nonhosts or with a high density of hosts.

Shelterwood

- Remove infected overstory trees within 10 years or after regeneration reaches 3 feet tall.

Uneven-aged management

- Selectively harvest heavily infected trees during routine stand entries. If you retain infected trees, favor those with infections in the lower half of the crown.
- When spacing trees, favor nonhosts in the vicinity of infected overstory trees.
- Use mixed-species management and concentrate on planting and favoring nonhost species in areas of infected trees.
- Thin bole-infected understory trees during routine stand entries.
- Reduce density and maintain wide spacing of understory host trees.

Uneven-aged, single-species lodgepole pine or ponderosa pine where no alternative species are available

- Remove the most heavily infected trees (DMR 4–6) when possible.
- Maintain wide spacing around heavily infected trees.
- Thin infected regeneration when possible.
- Reduce density and maintain wide spacing of understory host trees.
- In extreme situations, clearcut, burn, and start over.

Recreation areas

- Prune off large brooms (see Figure 7-5, page 89, for correct pruning technique).
- Favor nonhosts.

Wildlife management

- Retain some dwarf mistletoe-infected trees as appropriate.
- Use mixed-species management.
- To prevent DM from infecting the entire stand, isolate infected trees in patches, and favor nonhost trees around patches.
- Allow DMR 6 trees to develop but favor nonhost trees around these trees.

Leafy mistletoe management

Leafy mistletoes in Oregon conifers rarely are a management concern. However, if you believe management in incense-cedar or juniper is needed (Figure 10-8), the only effective control is pruning the branch to which the mistletoe is attached. In some cases, it may make sense to cut the entire tree to limit the amount of seed being produced and dispersed in the stand. However, since the seed is dispersed by birds, it is likely that birds may bring seed back into the area.

Photo: Dave Shaw, © Oregon State University

Figure 10-8. Incense-cedar mistletoe on incense-cedar.

CHAPTER 11

References and Resources

Government agencies

USDA Forest Service, Pacific Northwest Region 6, Forest Health Protection (FHP)

PO Box 3623, Portland, OR 97208-3623

http://www.fs.fed.us/r6/nr/fid/ index.shtml

FHP is involved in surveying and monitoring insects and diseases in Oregon, and it works with federal land managers to solve insect and disease problems. The FHP website is full of relevant information, publications, and maps of the current distribution of tree mortality in Oregon and Washington.

Field offices are in Sandy, La Grande, Bend, and Central Point; the regional forest pathologist and entomologist are based in Portland. See the website for contact details.

Oregon Department of Forestry

- Forest Health Program, 2600 State Street, Salem, OR 97310 http://www.oregon.gov/ODF/ForestBenefits/Pages/ForestHealth.aspx
- Stewardship Forester offices by county http://www.oregon.gov/ODF/Working/Pages/FindAForester.aspx

Oregon State University Forestry & Natural Resources Extension Program

Forestry and Natural Resources Extension programs, services, and offices throughout Oregon

http://extensionweb.forestry.oregonstate.edu/

Oregon State University Integrated Plant Protection Center

OSU Plant Clinic provides various services related to identification of plant diseases and insect pests. This is the place to send in plant samples; see website for details.

http://plant-clinic.bpp.oregonstate.edu/

Publications

Oregon State University Extension publications

Find the following and other publications on forest health online here: https://catalog.extension.oregonstate.edu/topic/forestry-and-wood-processing/forest-health-insects-and-disease

Ecology and Management of Eastern Oregon Forests: A Comprehensive Manual. 2018. Oester, P.T., S.A. Fitzgerald, N.A. Strong, R. Parker, W.H. Emmingham, G.M Filip, L.V. Henderson, T.L. Deboodt and D. Edge. Manual 12. Oregon State University, Corvallis, OR.

Pacific Northwest Insect Management Handbook. 2017. Hollingsworth, C.S., ed. Oregon State University, Corvallis, OR. http://pnwhandbooks.org/insect (revised annually)

Pacific Northwest Plant Disease Management Handbook. 2017. Pscheidt, J.W., and Ocamb, C.M., senior eds. Oregon State University, Corvallis, OR. http://pnwhandbooks.org/plantdisease (revised annually)

Pacific Northwest Weed Management Handbook. 2017. Peachey, E., ed. Oregon State University, Corvallis, OR. http://pnwhandbooks.org/weed (revised annually)

Pruning Western White Pine. 2006. Schnepf, C.C. and J.W. Schwandt. PNW 584. University of Idaho, Moscow, ID.

Field guides for identifying tree damage agents, especially insects and diseases

Reports in the Forest Insect and Disease Leaflet series, from the USDA Forest Service, are available for most major insects and diseases. http://www.fs.fed.us/r6/nr/fid/wo-fidls/

Reports in the Insect and Disease Pest Note series, from the Oregon Department of Forestry, are available online. http://www.oregon.gov/ODF/ForestBenefits/Pages/ForestHealth.aspx

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Insects and Diseases of Woody Plants of the Central Rockies. 2000. Cranshaw, W.S., D. Leatherman, W. Jacobi, and L. Mannix, eds. Bulletin No. 506A. Colorado State University Cooperative Extension, Fort Collins, CO.

Diseases of Trees and Shrubs, 2nd ed. 2005. Sinclair, W.A., and H.H. Lyon. Cornell University Press, Ithaca, NY.

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Our companion guide

Field Guide to the Common Diseases and Insect Pests of Oregon and Washington Conifers. 2006. Goheen, E.M., and E.A. Willhite. USDA Forest Service, Pacific Northwest Region. R6-NR-FID-PR-01-06. Portland, OR.

Available from U.S. Government Printing Office

http://www.gpo.gov/

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Notes

Managing Insects and Diseases of Oregon Conifers

Photo: Edward C. Jensen, © Oregon State University

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