Manual 10 • November 1998
$5.50

Forest Insect Ecology and Management in Oregon

Oregon State University Extension Service

Forest Insect Ecology and Management in Oregon

Gregory M. Filip
Extension Forest Protection Specialist,
Oregon State University

David L. Overhulser
Forest Entomologist,
Oregon Department of Forestry

Paul T. Oester
Extension Forestry Agent,
Union County,
Oregon State University

Acknowledgments

The authors wish to thank Andy Eglitis, forest entomologist, USDA Forest Service, Bend, Oregon; Timothy Schowalter, professor of entomology, Oregon State University; and Don Goheen, forest pest specialist, USDA Forest Service, Central Point, Oregon for technical review.

Figure credits

Andy Eglitis: Figures 5–8, 10, 26
Oregon Department of Forestry: Figures 11, 12, 14, 16–18, 21, 24
U.S. Forest Service: Figure 19
Greg Filip: Figure 22
R.B. Smith: Figure 23
Dave Paine: Figure 4
Debby Sundbaum-Sommers: Figure 27
Russ Mitchell: Figure 13
Ken Wright: Figure 20
Borys Tkacz: Figure 25

Contents

Chapter 1. Introduction **1**
- Forest health 1
- Insect life cycles 2
- Biotic and abiotic factors affecting insects 2
- Important insect groups 4

Chapter 2. Foliage-feeding Insects **5**
- Aphids 5
- Budworms 5
- Caterpillars 8
- Flea beetles 11
- Loopers 11
- Midges 11
- Miners 12
- Sawflies 13
- Scales 13
- Webworms 14
- Ecologic roles of foliage-feeding insects 14
- Management of foliage-feeding insects 15

Chapter 3. Shoot- and Twig-feeding Insects **17**
- Aphids 17
- Beetles 17
- Borers 17
- Midges 20
- Moths 20
- Scale 20
- Weevils 20
- Ecologic roles of shoot- and twig-feeding insects 21
- Management of shoot- and twig-feeding insects 22

Chapter 4. Trunk- and Large-branch-feeding Insects **23**
Aphids 23
Pitch moths 23
Flatheaded borers 23
Bark beetles 26
Ecologic roles of trunk- and large-branch-feeding insects 30
Management of bark beetles 31

Chapter 5. Root-feeding Insects **33**
Root-feeding bark beetles 33
Root- and root-collar-feeding weevils 33
Ecologic roles of root-feeding insects 36
Management of root-feeding insects 36

Chapter 6. Effects of Forest Practices on Insects **37**
Precommercial thinning 37
Commercial thinning, seed tree harvesting, and shelterwood harvesting 37
Sanitation-salvage harvesting 37
Clearcutting and regeneration 38
Uneven-age management 38
Prescribed burning 39
Fertilizing 39
Aerial insecticide application 40
Artificial branch pruning 40

Conclusions **43**

References **45**

Glossary **47**

Index **50**

Introduction

This manual is intended for forest land owners and managers who want to understand and prevent unnecessary forest damage from insects. This manual covers only insects that infest living trees, not those that infest dead wood.

The manual is organized into chapters based on the part of the tree that is affected by insects: foliage, shoots and twigs, trunks and large branches, and roots.

Some insect groups appear in several chapters because they affect more than one part of the tree. For example, some aphids affect foliage as well as twigs and branches.

The following example illustrates how a woodland owner or manager would use this manual:

1. Observe the tree damage; for example, a dead terminal branch on a Sitka spruce.
2. Determine what part or parts of the tree are affected; in our example, only terminal branches are dead, not lateral branches.
3. Identify the tree species, keeping in mind that more than one species may be affected. In our example, only spruce is affected; hemlocks and firs are healthy.
4. Look in the tables under tree species and part damaged. In this case, look up Sitka spruce under "shoot- and twig-feeding insects," Table 2 in Chapter 3.
5. Identify the possible insect group. In our case, four insects are listed that infest Sitka spruce: aphids, beetles, moths, and weevils.
6. Refer to the appropriate chapter for specific identification and management options. In our example, the damage resembles that caused by white pine weevil described in Chapter 3.
7. If you cannot identify the insect, send samples to your OSU Extension agent or Oregon Department of Forestry forester.

This manual is a companion to *Forest Disease Ecology and Management in Oregon*. See the References section for other related publications.

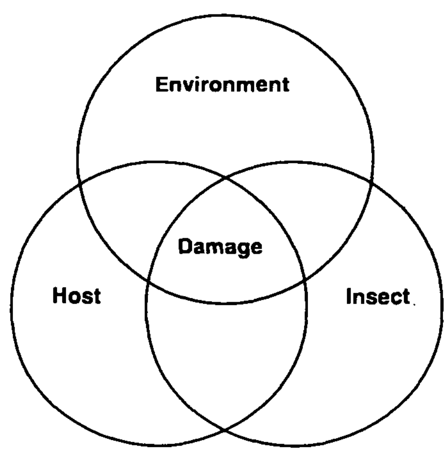
Forest health

Good forest health is a condition that implies a resiliency to natural disturbances such as insect damage, tree diseases, fires, and wind. It also implies that forest managers can achieve management objectives without impairing this resiliency.

Disease, fire, and wind may be related to insect-caused damage in many ways. For example, insect-caused mortality may increase the likelihood of fire, or wind damage may increase a tree's susceptibility to some insect pests. Thus, insect-caused disturbances or damage often involve more than the simple interaction of insects and their host trees.

Insect damage is the product of three interacting factors: the host (tree), the insect, and the environment (Figure 1). If any one of these factors is missing or unfavorable, damage will not occur. For

Figure 1.—The damage triangle.



example, assume a susceptible tree species is present, and spruce budworm larvae are feeding on the foliage. However, the spring weather is too cold for the larvae to develop and they are eaten by birds. In this case, the environment for insect development is not optimum—the weather is too cold—so defoliation does not occur even though the host and budworm are present.

Insect life cycles

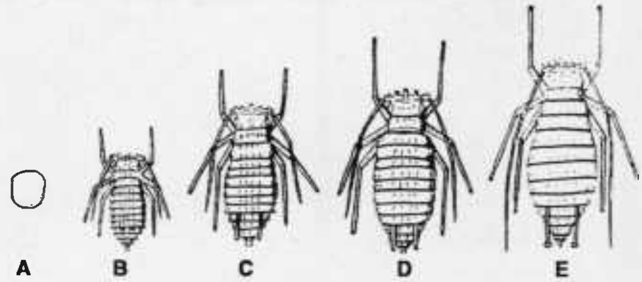
There are more than 900,000 identified species of insects in the world, more than any other kind of animal. Insects are arthropods, a group of organisms that also includes crustaceans, spiders, and mites. Although spiders and mites are related to insects, most of the arthropod damage to forest trees in Oregon is caused by insects. This guide focuses on insects and discusses other arthropods only briefly.

Insects go through distinct stages of development, from eggs to adults, called *metamorphosis*. Metamorphosis may take a few weeks to several years. Knowing what kind of metamorphosis an insect goes through will help in identification, since often only one life stage of the insect is present on damaged tree parts.

In *incomplete* or *simple* metamorphosis, insects change from eggs to nymphs to adults (Figure 2). The nymphs resemble the adults. Aphids are examples of insects with incomplete metamorphosis.

In *complete* metamorphosis, insects change from eggs to larvae to pupae to adults (Figure 3). In this case, the larvae are completely different from the adults in appearance and habits. Budworms and bark beetles are examples of insects with complete metamorphosis.

Figure 2.—Incomplete or simple metamorphosis.



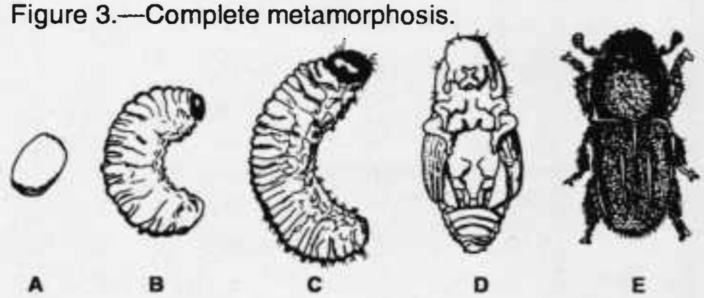
Not only do insects change form during the growing season, but populations also increase or decrease from year to year or even decade to decade. These cycles often are somewhat predictable over the course of 20 or more years. For example, tussock moth populations seem to peak for 1 or 2 years every 10 years. Budworm populations peak for 10 years every 20 years.

Climate, food, and natural enemies are major factors affecting insect populations. It is important to understand insect population dynamics and the factors that affect them in order to know when and how to control undesirably high populations of certain damaging insects.

Biotic and abiotic factors affecting insects

Biotic factors are the living parts of an insect's environment. Food supply is an important biotic factor that limits insect populations. Some insects feed on several tree species, while others rely on only one species of host tree. Defoliating insects usually have an abundant food supply,

Figure 3.—Complete metamorphosis.



but specific kinds of foliage sometimes are limited. For example, some defoliators such as the spruce budworm feed on only newly developing foliage. Other defoliators such as the pandora moth feed on only older foliage. Some bark beetles require old or dying trees. If these trees are in short supply, beetle populations remain low.

Many *abiotic* (nonliving) factors also regulate insect populations. For example, temperatures that are too high or too low kill insects. Extremely low temperatures (below -20°F) can kill bark beetles. Most insects cannot live above 120°F. Temperatures also affect insect development. Therefore, increased altitude or latitude can prolong the time required for insect development.

Moisture and drought can have profound, although indirect, effects on insect populations. Water stress alters trees and their environment, making trees more susceptible to insect attack. Under these conditions, certain insects grow faster and have higher survival rates. On the other hand, some insects are vulnerable to desiccation (drying out) especially during molts (skin shedding). Drought can be induced either by lack of precipitation or by heavy competition among trees in an overstocked stand. Too much water resulting from flooding or raised water tables also can stress trees and make them more susceptible to insect attack.

Wind, snow, and ice affect insects directly and indirectly. Wind currents carry insects farther than they normally fly. Indirectly, wind, often in combination with snow and ice loading, can result in windthrown or broken trees. The broken trees and tops are ideal breeding material for certain bark beetles.

Lightning and fire influence forest insects by affecting their hosts. Both can severely weaken or kill trees, making them more susceptible to bark beetle and wood borer attack. Trunk wounds created by lightning or fire often are invaded by microorganisms. The increased resin flows and volatile odors accompanying wounds also attract bark beetles. On the other hand, fire, either natural or prescribed, can benefit a forest by killing insects that live in the duff and by thinning overstocked stands.

Tree wounds caused by humans, animals, or other trees or objects can weaken trees and increase their susceptibility to bark beetles and wood-boring insects. As wounds to trunks, branches, or roots get bigger and older, they are more likely to experience decay caused by fungi and other microorganisms. The decayed wood then is susceptible to wood-boring insects. If the wound is large enough, a tree may be weakened sufficiently to be attacked and killed by bark beetles.

Slash created from live branches, tops, and stumps makes excellent breeding material for many forest insects. Twig and branch insects dwell in the smaller material; bark beetles and wood borers live in the larger wood pieces, especially those more than 3 inches in diameter. The pitch volatiles released when cutting slash are very attractive to many insects that attack and breed in the inner bark and sapwood. If enough slash is present and insect populations become large, standing green trees can be attacked and killed by bark beetles such as pine engravers.

Disease can predispose trees to insect attack. Root diseases in particular can weaken trees and make them more susceptible to bark beetle attack. Douglas-fir beetles are especially likely to infest Douglas-firs that already are affected by laminated root rot. Fir engraver beetles commonly infest white or grand fir that is affected by laminated root rot, Armillaria root disease, or annosus root disease. White pine blister rust can weaken white pine so that it is more susceptible to mountain pine beetle. Dwarf mistletoes also can predispose trees to bark beetles.

Natural enemies of insects can have profound effects on insect populations. Natural enemies include other insects, spiders, microorganisms, birds, and mammals. For example, parasites such as wasps or flies lay their eggs on larvae or pupae of their host insects. The eggs hatch, and the developing parasite larvae feed on the host and kill it. Arthropod predators include spiders, ants, and true bugs that hunt down, snare, or ambush other insects. Birds and small mammals are the major vertebrate predators of forest insects. Pathogens are disease-causing organisms such as fungi, viruses, or bacteria that infect and kill their insect hosts.

Introduced or non-native insects can affect insect populations. Introduced insects have a beneficial effect when they become parasites or predators of damaging insects. Intentional introductions are used to control a target insect pest such as the larch casebearer.

On the other hand, introduced insects can affect host trees so dramatically that the trees are killed or are weakened enough to be more attractive to other insects. For example, in the eastern United States, the gypsy moth predisposes oak to bark beetles. Introduced insects may cause particularly severe damage because they may lack natural enemies to keep their populations in check.

Important insect groups

There are several main groups or orders of insects, but only three cause severe damage to living trees in Oregon: aphids and scales (Homoptera), butterflies and moths (Lepidoptera), and beetles (Coleoptera). Two other orders may cause moderate damage: midges (Diptera) and sawflies (Hymenoptera).

These important forest insects can be grouped by the part of the tree they affect. These groups include foliage-feeding insects, shoot- and twig-feeding insects, trunk- and large-branch-feeding insects, and root-feeding insects.

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. 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.

Foliage-feeding Insects

The important foliage-feeding insects of Oregon include aphids, budworms, caterpillars, flea beetles, loopers, midges, miners, sawflies, scales, and webworms (Table 1).

Aphids

Aphids are small, soft-bodied insects that may have several generations annually. Most are parthenogenic, i.e., they reproduce asexually. They overwinter mainly as eggs, and some species require two species of hosts. Aphids have piercing mouth parts through which they suck plant sap from foliage, twigs, and even roots. They produce a sweet, sticky substance called honeydew that attracts ants and is a good medium for sooty mold. Adelgids are similar to aphids, and both sometimes are referred to loosely as aphids.

The most important foliage-feeding aphids in Oregon are found on Sitka spruce and Douglas-fir (Table 1). The most common aphids are the spruce aphid on spruce and the Cooley spruce gall aphid on spruce and Douglas-fir.

The **spruce aphid** (*Elatobium abietinum*) affects Sitka and most ornamental spruces in Oregon. This insect probably was introduced to North America from Europe. On the coast, spruce aphids are present on trees all year and have several generations each year. Mild winter temperatures, typical of the coast, may favor destructive aphid outbreaks.

Aphid populations increase dramatically in late February and early March. Aphids suck the sap from spruce needles, causing yellow patches at the feeding site. The heaviest damage is in the lower or mid crown of the tree. By May, damaged needles turn completely brown and drop.

Figure 4.—Cooley spruce aphid galls.

The **Cooley spruce gall adelgid** (*Adelges cooleyi*) causes a gall on spruce twigs (Figure 4) and a yellowing and twisting of Douglas-fir needles, which is noticeable in spring. Neither kind of damage is of much economic importance in forest trees. On nursery seedlings and ornamental trees, however, the aphids tend to stunt and deform new growth.

The galls form on spruce, but on Douglas-fir, the presence of aphids is marked by cottony tufts on the needles. When both hosts are present, there are six stages in addition to eggs and crawlers. If one host is absent, there are only three stages. The entire life cycle requires 2 years.

Budworms

Budworms get their name from the larvae that feed on developing buds and new foliage. The most important budworms in Oregon affect true firs, Douglas-fir, western hemlock, Engelmann spruce, and some pines (Table 1).

Table 1.—Foliage-feeding insects of Oregon trees. Insect groups marked in bold are discussed in text.

Tree species	Aphids	Budworms	Caterpillars	Loopers	Midges	Miners	Sawflies	Scales	Webworms
Conifers									
Cedar									
Alaska-			x						
Incense-			x						
Port-Orford-			x						
Western red			x	x				x	
Fir									
Douglas-	**X**	**X**	**X**	**X**	**X**	x	x	**X**	**X**
Grand/White	x	**X**	**X**	**X**		**X**	x		**X**
Noble	x								
Pacific silver	x	**X**		x		x	x		
Shasta red						x			
Subalpine	x	**X**	**X**	x					
Hemlock									
Mountain		x				x	x		
Western		**X**	x	**X**		x	**X**	**X**	x
Juniper			x			x	x	x	x
Larch	x	x	x	x		**X**	**X**		
Pine									
Jeffrey	x		**X**			**X**	**X**	**X**	
Knobcone						x		**X**	
Limber		**X**				x			
Lodgepole	x	**X**	**X**	x		**X**	**X**	**X**	**X**
Ponderosa	x	**X**	**X**	x	x	**X**	**X**	**X**	**X**
Sugar	x	**X**	**X**			**X**	**X**	**X**	
Western white	x		x				**X**		
Whitebark	x								
Redwood	x								
Spruce									
Brewer	x								
Engelmann	x	**X**	**X**	x		**X**	x		
Sitka	**X**	x	x	**X**		x	x		**X**
Yew									

Table 1.—Foliage-feeding insects of Oregon trees (continued).

	Aphids	Beetles	Budworms	Caterpillars	Loopers	Miners	Sawflies	Scales	Webworms
Hardwoods									
Alder	x	X		X	x	x	X	x	X
Ash									X
Aspen			X	X	x	x			
Birch	x			X	x		x		
Buckthorn									
Cherry				X			x		X
Chinkapin				X					
Cottonwood		x		X		x	x		
Dogwood									
Madrone				X		x			X
Maple	x								
Myrtlewood						x			
Oak	x				X				
Tanoak				X					
Willow	x			X	x	x	x	x	x

Adult moths lay eggs on foliage in late summer. Eggs either overwinter or hatch in the fall into larvae that hibernate in bud scales or in hibernacula (an individual light silken web) on bark. Beginning in the spring, the larvae feed on buds and newly emerging foliage and go through several stages or instars before pupating in the summer. The pupae hatch into adult moths (Figure 5).

The **western spruce budworm** (*Choristoneura occidentalis*) is one of the most destructive foliage-feeding insects in Oregon. Millions of acres of susceptible Douglas-fir, spruce,.and true firs (except noble and red fir) have been defoliated. When budworm populations are high, all new foliage can be stripped from host trees.

Outbreaks typically last 10 years in eastern Oregon. Three to 5 years of defoliation can reduce tree growth, cause top-kill, and kill some trees, especially seedlings and saplings. Mature trees also can die, especially when subsequently attacked by bark beetles. Cone crops on host trees can be destroyed during outbreaks. Western spruce budworm outbreaks can occur on the western slopes of the Cascade Mountains, but defoliation usually lasts for only a few years.

In May and June, when foliage growth starts, budworms frequently "web" together adjacent shoots, giving trees a twisted or stunted appearance. Attacked tips eventually turn red, making an infested stand look scorched. Older larvae often feed on older foliage during outbreaks. The upper crown often looks bare after several years of feeding. Ants and birds are significant predators of budworm larvae.

Other budworm species occur in Oregon but are not nearly as destructive as the western spruce budworm. The **western blackheaded budworm** (*Acleris gloverana*) also can cause significant defoliation of hemlock, Douglas-fir, true firs, and spruce in western Oregon. The **modoc budworm** (*Choristoneura viridis*) primarily defoliates white fir in southern Oregon. The **sugar pine tortrix** (*Choristoneura lambertiana*) feeds on several pines in Oregon. The **large aspen tortrix** (*Choristoneura conflictana*) can cause 1 or 2 years of defoliation of aspen stands.

Figure 5.—Adult budworm moth.

Caterpillars

Caterpillars are multilegged, often brightly colored, and occasionally covered with hairs. They are the larval stage of adult moths or butterflies. The most important caterpillars in Oregon affect Douglas-fir, true firs, pines, spruce, and several species of hardwoods (Table 1). The most destructive caterpillars in Oregon are larvae of the Douglas-fir tussock moth, the western tent caterpillar, the pine butterfly, and the pandora moth. An introduced caterpillar is the gypsy moth.

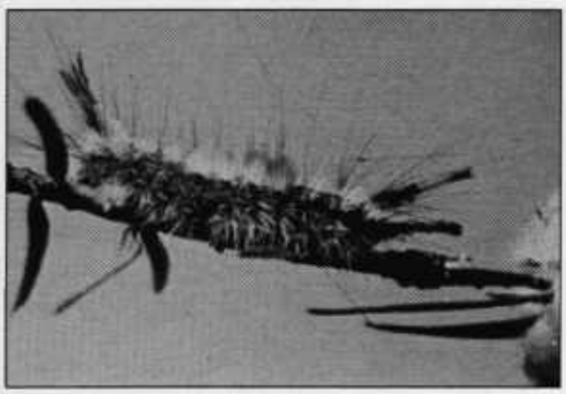
Among the most destructive caterpillars, especially in eastern Oregon, are the larvae of the **Douglas-fir tussock moth** (*Orgyia pseudotsugata*, Figure 6). Outbreaks in Douglas-fir and true fir develop suddenly over thousands of acres and collapse after 1 or 2 years of intense defoliation. Engelmann spruce and ornamental spruces also are defoliated. Tussock moth defoliation can cause tree growth loss, top-kill, and mortality, but some fully defoliated trees can recover.

After eggs hatch in late May or early June, young larvae congregate at the tops of trees and drop on silken threads. These silken threads act like parachutes and allow the larvae to be carried by the wind to adjacent trees. The residual silk at the tree top forms a small tent that is one of the first signs of a tussock moth infestation.

Initially, larvae feed on the current year's foliage, causing it to shrivel and brown. Unlike young budworms, however, tussock moth larvae feed on all ages of foliage.

By mid-July to August, the maturing larvae develop tufts of hairs or tussocks. Pupae form in late July and August and hatch into adult moths in mid-August. The female moth is flightless. Eggs are laid in clusters in August–September. The eggs overwinter and hatch in May.

Figure 6.—Tussock moth larvae.



The **rusty tussock moth** (*Orgyia antiqua*) is a widespread insect that feeds on hardwood and conifer foliage. In western Oregon, it causes localized defoliation in red alder stands. The caterpillars resemble the Douglas-fir tussock moth, but have four distinctive golden brushes of hair on their backs.

The **western tent caterpillar** (*Malacosoma californicum*) is the most common insect pest of hardwoods in Oregon. During outbreaks, which can last 2 or 3 years and cover thousands of acres, trees are partially or completely defoliated. Unsightly trees and thousands of caterpillars often cause public alarm, but tree mortality is rare. In eastern Oregon, outbreaks can kill some branches on bitterbrush, an important browse for deer.

In April and May, caterpillars construct and enlarge white, silken tents while consuming adjacent foliage. Tree limbs with tents often are completely defoliated. Pupae form in midsummer and hatch into adult moths. Eggs usually are covered with a yellow to brown frothy substance produced by the female. The eggs overwinter and hatch into caterpillars in the spring at budbreak.

The **pine butterfly** (*Neophasia menapia*) is a pest of ponderosa pine, particularly old-growth, in Oregon. Defoliated stands can die, especially if trees already are stressed by bark beetles. During outbreaks, the larvae also may feed on associated conifer species. Outbreaks last only a few years. Very large numbers of butterflies often are seen before significant defoliation occurs.

The larvae feed in clusters when young, but as they mature they begin to feed singly. Old needles are eaten first, but older larvae also eat new needles. Larvae attach to bark, needles, twigs, or other objects before changing to pupae.

Figure 7.—Adult pine butterfly.

Adults (Figure 7) fly in late summer and lay eggs in rows along needles. The eggs overwinter and hatch in June or about the time of budbreak.

The **pandora moth** (*Coloradia pandora*) is another destructive insect of ponderosa pine, but sometimes also defoliates lodgepole pine, Jeffrey pine, and sugar pine. Severe defoliation can cause tree growth loss, but mortality is uncommon unless trees are stressed by factors such as drought or attack by other pests. Unlike most other insect defoliators in Oregon, the pandora moth has a 2-year life cycle. Populations last three or four generations (6 to 8 years) before a naturally occurring virus causes a population crash.

Tree ring studies have shown that central Oregon has experienced 10 outbreaks of pandora moth in the past 500 years, suggesting that the moth reaches high levels fairly rarely. Nonetheless, the pandora moth is a significant associate of pines in the region. The most recent

Figure 8.—Pandora moth larvae.

outbreak subsided in 1995, with defoliation being noted on only 2,000 acres in 1996.

The larvae (Figure 8) hatch in late August and September and climb into trees to begin feeding. During winter, they hibernate in clusters at the base of needles. They feed again from March to early July. Caterpillars then move down the tree and burrow in the soil, where they pupate for 1 year.

In June or July of the second year, the adult moths emerge to mate. Eggs are laid in July and August on foliage, bark, buildings, or other structures.

Because larvae feed on the previous year's needles in the fall, trees at first appear completely defoliated. However, they leaf out again in the spring, creating a thinly foliated appearance.

The **gypsy moth** (*Lymantria dispar*) is introduced periodically into Oregon and usually is eradicated by aggressive aerial spraying with insecticides. There are two forms: a European form and an Asian form. The European gypsy moth is a major pest in the eastern United States, where it was introduced in 1870. It occasionally appears in Oregon, probably as a result of egg masses being transported on automobiles and recreational vehicles from the east. The European gypsy moth feeds mostly on hardwoods, but when introduced into Oregon quickly converted to feeding on Douglas-fir before being eradicated.

The Asian gypsy moth can spread faster than its European cousin because female moths can fly up to 12 miles and the larvae feed on more plant species. The Asian gypsy moth was introduced into Oregon as egg masses attached to Russian grain ships. The population was quickly eradicated with aerial sprays, but this pest remains a threat, especially on unprocessed logs imported from eastern Asia.

Flea beetles

Flea beetles are small, shiny-colored, oval-shaped beetles that feed on the leaves of hardwoods. One of the most common defoliators of red alder in western Oregon is the alder flea beetle (*Altica ambiens*). Both the larvae and adults of this beetle voraciously consume foliage. During outbreaks, which normally last 1 to 2 years, stands of alder can be totally defoliated by midsummer. Defoliated trees usually are not killed.

Loopers

Loopers, also known as "inchworms," are larvae that move along twigs with a looping motion. The most destructive loopers in Oregon are the western hemlock looper and the western oak looper (Table 1).

The **western hemlock looper** (*Lambdina fiscellaria lugubrosa*) often is destructive in mature hemlock forests. Associated Sitka spruce, Douglas-fir, and understory shrubs also can be defoliated. Tree mortality can occur, but trees with up to 75 percent defoliation can recover. Outbreaks last about 3 years.

Feeding begins in May, June, and early July, but this initial defoliation is not noticeable. From the middle of July to October, loopers feed heavily, causing infested trees to appear scorched.

In late summer to fall, loopers drop from silken threads to the ground to pupate in protected places. Adult moths hatch in 10 to 14 days and lay eggs in late September and October. The eggs overwinter and hatch in the spring.

The **western oak looper** (*Lambdina fiscellaria somniaria*) feeds on Oregon white oak and associated trees in Oregon. In the Willamette Valley, white oak stands can be defoliated over extensive areas, but tree mortality is not common. The life cycle is similar to that of the hemlock looper, and outbreaks can last up to 5 years.

Midges

Midges are small flies that feed on needles of conifers. The **Douglas-fir needle midge** (*Contarinia* spp.) lays eggs in the new needles of Douglas-fir in the spring, and larval feeding results in a discolored area on both surfaces of the needle. The infested needles turn brown during the summer and drop off during the winter. Needle midge outbreaks have defoliated hundreds of acres of Douglas-fir in northeast Oregon, but usually last only 1 or 2 years.

Figure 9.—Adult larch casebearer.

Miners

Miners are larvae that feed within needles or leaves of attacked trees rather than on the outside. The most damaging miners in Oregon occur on pine and larch (Table 1). The most destructive foliage miners in Oregon are the pine needle-sheath miner, the lodgepole needle miner, and the larch casebearer.

The **pine needle-sheath miner** (*Zellaria haimbachi*) feeds on ponderosa, Jeffrey, and lodgepole pine in both eastern and western Oregon. Defoliation can seriously deform the tops of young trees. After 2 or more years of defoliation, terminal shoots often die and stems become forked.

The adult moth lays eggs on current foliage from late June to early August. After 10 days, the eggs hatch and the larvae bore into needles, where they overwinter.

In spring, when shoot elongation begins, larvae bore out of the previous year's needles, migrate to new growth, and chew small holes in the sheath of young needles, causing them to stop elongating and turn yellow. Needles that are severed at the base tend to droop, die, and fall prematurely. As larvae move among fascicles, they produce a fine silk webbing. Pupation occurs in June and July.

The **lodgepole needle miner** (*Coleotechnites* sp.) also attacks lodgepole and ponderosa pine and sometimes white fir, sugar pine, and Engelmann spruce. Outbreaks occur predominantly in areas where lodgepole pine is the climax species with an understory of bitterbrush. Defoliation results in tree growth loss.

Eggs hatch in late summer, and the larvae migrate to new needles where they construct mines. The larvae pupate in early July the following year. The adult moths hatch in late July.

The **larch casebearer** (*Coleophora laricella*) was introduced from Europe to the eastern United States in 1886. It gradually spread into Oregon by the 1960s, an unwanted traveler along the Oregon Trail! At one time, it caused considerable defoliation of larch, but recently it has been controlled by the introduction of insect parasites from Europe, one of the most successful biological control efforts in western forests.

Heavily infested trees become reddened as though scorched. Defoliated trees refoliate later in the summer. Repeated defoliation reduces tree growth, and mortality may result when other pests attack the weakened trees.

The adult moths lay eggs on needles from late May until early July. The eggs hatch into larvae, which start life as miners and feed on new foliage. They later live and feed in caselike shelters comprised of hollowed-out needles, where they eventually overwinter. In the spring, they pupate and hatch into moths (Figure 9).

Sawflies

Sawflies get their name from the sawlike ovipositor on adult wasps (Figure 10) that is used for inserting eggs in plant tissue. Sawflies are most damaging on hemlock, pine, and larch (Table 1). The most important foliage sawflies in Oregon are the hemlock sawfly, the pine sawfly, the larch sawfly, and the lodgepole pine sawfly.

The **hemlock sawfly** (*Neodiprion tsugae*) is an important defoliator of hemlock in coastal Oregon. The larvae feed chiefly on older needles, causing tree growth loss rather than mortality. Larvae hatch in the spring and feed in late spring and early summer. Cocoons usually are formed in the duff, but sometimes on needles and other surfaces. Adults emerge from cocoons in the fall and lay eggs, which overwinter.

The **pine sawfly** (*Neodiprion fulviceps*) can defoliate ponderosa, Jeffrey, sugar, and white pine in Oregon. The life cycle is similar to that of the hemlock sawfly. The **larch sawfly** (*Pristiphora erichsonii*) attacks larch and overwinters as prepupal larvae.

The **lodgepole pine sawfly** (*Neodiprion* sp.) attacks all age classes of lodgepole pine during outbreaks. Defoliated trees have reduced vigor and sometimes are killed by bark beetles.

Figure 10.—Sawfly adults.

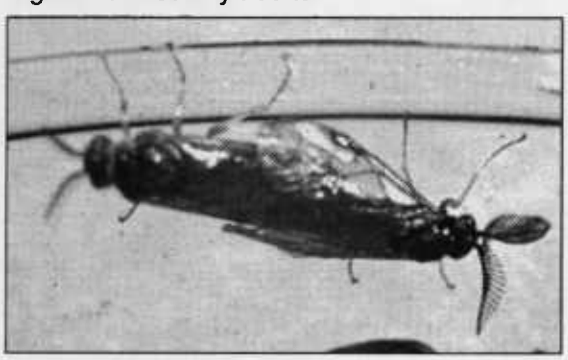


Figure 11.—Black pineleaf scale.

Scales

Scales are sap-sucking insects that often are inconspicuous, have a waxy shell-like covering, and remain fixed in one position until they die (Figure 11). In Oregon, foliage scales have been reported on Douglas-fir, juniper, pine, alder, and willow. In southern Oregon, they can be abundant on pine as a result of mosquito spraying that affects their natural enemies (wasps). The most important foliage scales in Oregon are the pine needle scale and the associated black pineleaf scale.

The **pine needle scale** (*Chionapsis pinifoliae*) attacks all species of pines and sometimes Douglas-fir and hemlock. It often is a pest of ornamentals but also can occur in the forest, especially along dusty roads. Heavily infested trees have foliage that appears white from the scales. Young trees can be killed, but usually only growth loss occurs. Eggs are laid in the fall, overwinter under female scales, and hatch in the spring. The feeding nymphal stage is covered with a white-colored shell.

The **black pineleaf scale** (*Nuculaspis californica*) attacks primarily pines and sometimes Douglas-fir. Affected foliage is stunted at the tips of twigs, with individual needles appearing yellowish and encrusted with scales. Eggs are laid in the spring and early summer and hatch into crawlers. These scales are distinguished by the black shell that covers their feeding stage (Figure 11). Severe scale infestation over several years can so weaken trees that they become susceptible to bark beetle attack.

Webworms

Webworms are caterpillars that make large webs over the foliage they feed on. In Oregon, they feed on Douglas-fir, true fir, spruce, pine, and several hardwoods. The most important webworms in Oregon are the silver-spotted tiger moth and the fall webworm.

The **silver-spotted tiger moth** (*Halisodota argentata*) is the most common defoliator of Douglas-fir, true fir, spruce, and pine in western Oregon. Whole branches often are stripped of needles, giving trees an unsightly appearance. Tiger moth caterpillars (Figure 12) are the most common defoliating insects present on conifer foliage during the winter. From September to April, the caterpillars cluster inside dense webs covering one or more branches.

Figure 12.—Silver-spotted tiger moth caterpillar.

In May and June, the webs may be present, but the caterpillars abandon the web and disperse over the tree. Between mid-June and August, the pupal, moth, and egg stages predominate, and caterpillars are not present.

The **fall webworm** (*Hyphantria cunea*) is an important defoliator of hardwoods in Oregon. Adults lay eggs in the summer on leaf undersides. The larvae feed together and form large webs. In September, the larvae form thin transparent cocoons in the soil, litter, or on tree trunks.

Ecologic roles of foliage-feeding insects

Foliage-feeding insects traditionally were thought to be destroyers of the forest, pests to be controlled and eradicated. Certainly they can and have caused tremendous economic damage to Oregon's forests. Their beneficial roles in forest ecosystems are just beginning to be studied and accepted.

One obvious role is as a source of food for other wildlife, especially birds, but also bats, rodents, spiders, and ants. One study in northeastern Oregon showed that trees where birds and ants were excluded had 10 times as many budworms as trees where birds and ants could feed on budworms at will. Insects are most vulnerable to predators as larvae, but adult moths and butterflies also are an important food source. Pupae also are consumed; for example, ground squirrels eat the large pandora moth pupae.

Another important role of foliage-feeding insects is their ability to recycle nutrients in foliage back to the forest floor as partially consumed foliage and insect frass (boring wood dust). This function is especially important when forest stands are overstocked and soil nutrients become scarce.

For example, western spruce budworms defoliate and kill millions of fir trees in overstocked stands during an epidemic. The surviving pines and resistant firs benefit from the newly created growing space and nutrients from dead needles, branches, trunks, and roots. The accumulation of fuels during budworm outbreaks supports fires that favor the regeneration of non-host conifers such as pine and larch.

Some research has been done on the site and stand conditions that favor the development of problem situations with defoliating insects, especially western spruce budworm and Douglas-fir tussock moth. Little is known about environmental conditions that favor other species of foliage-feeding insects.

The chief hosts for western spruce budworm and Douglas-fir tussock moth are true firs and Douglas-fir. Fire exclusion and selective harvesting of pine at the turn of the century resulted in an unprecedented abundance of true firs and Douglas-fir in eastern and southern Oregon. Many areas became overstocked with fir, resulting in excessive moisture stress on all trees on the site.

Overabundance of fir foliage, several years of drought, and above-normal temperatures allow defoliator populations to increase. Because food is abundant, larvae develop more quickly, thus limiting predation by birds and ants. Tree mortality is accentuated by bark beetles, other pests, and drought, thus increasing the risk of catastrophic wildfire.

Management of foliage-feeding insects

Management or control of foliage-feeding insects depends on the management objectives for the forest. Where timber production is to be maximized, certain management practices can reduce the impact of insects. Even when other resource values, such as recreation, aesthetics, or wildlife are more important than timber, some management may be needed to prevent the severe epidemics that result in widespread tree mortality.

Direct control measures for foliage-feeding insects traditionally have relied on aerial spraying with insecticides (see the section on aerial spraying). Insecticides applied from either helicopters or fixed-winged aircraft cover large acreages and reach the tops of trees.

Chemicals such as DDT and carbaryl were used in the past, but today's preferred tools include biological insecticides such as Bt (short for *Bacillus thuringiensis*), a natural bacterium that occurs in caterpillar populations and leads to their natural decline. Biological insecticides are applied when larvae or caterpillars are present, so that the pests ingest the material as they feed on foliage.

Direct control with insecticides does not alter the stand conditions that support defoliator outbreaks, such as overstocked multistoried stands of susceptible hosts. Thus, indirect control using silvicultural techniques is a better long-term approach. Thinning or harvesting of susceptible host trees leaves more space, nutrients, and moisture for residual trees so they are better able to defend against defoliator attacks. In mixed-species stands, non-host species are retained during thinning or harvesting. When regenerating a new stand, consider whether or not the species planted is susceptible to foliage-feeding insects.

A third management technique for foliage-feeding insects involves the use of introduced natural enemies and is called biological control. This technique is especially effective against exotic pests such as the larch casebearer. Introduced pests lack natural enemies to keep pest populations at low levels. Natural enemies, such as other insects, are imported from the pest's country of origin and introduced into the pest's new environment. For example, introduction of parasitic wasps from Europe into North America may have eliminated the larch casebearer as a damaging insect to western larch. This approach requires a thorough understanding of the ecology of both the pest and the natural enemy.

Shoot- and Twig-feeding Insects

The important shoot- and twig-feeding insects of Oregon include aphids, beetles, borers, midges, moths, scales, and weevils (Table 2).

Aphids

Along with foliage, aphids also attack the shoots and twigs of susceptible trees. The most important shoot- and twig-feeding aphids in Oregon are found on spruce and some true firs (Table 2). The most damaging are the balsam woolly adelgid on true firs and the Cooley spruce gall aphid, mentioned previously, on spruce (see Chapter 2).

The **balsam woolly adelgid** (*Adelges piceae*) was introduced from Europe and has caused severe damage and mortality to Pacific silver, subalpine, and grand fir in Oregon (Figure 13). Above 3,500 feet in elevation, noble fir and Shasta red fir are resistant to attack.

This aphid feeds on twigs, branches, and stems. It damages hosts by injecting a salivary substance into the tree that causes calluses and galls on the twigs and branches (gouting), which slowly weakens the tree and reduces seed crops. Bole infestations can be heavy and kill the tree.

In Oregon, there are two to four generations per year, and the crawlers are wind disseminated. All individuals are female.

Beetles

Adult beetles are hard-bodied insects with wings. The most important shoot- and twig-feeding beetles in Oregon are the twig beetles, which include several species of non-aggressive beetles (i.e., they kill only very weak trees). Twig beetles usually bore into the pith or reproduce under the bark of twigs, branches, and stems of susceptible trees.

Figure 13.—Balsam woolly adelgid damage.

The **Douglas-fir twig beetle** (*Pityophthorus orarius*) is the most common twig beetle in Oregon. It bores into the lateral twigs of Douglas-fir.

Borers

Borers get their name from their larvae's habit of boring through the pith of infested twigs and shoots (Figure 14). The most important shoot- and twig-feeding borer in Oregon is the **western pineshoot borer** (*Eucosma sonomana*).

The larvae of this species feed in the pith of terminal and lateral shoots of young ponderosa, Jeffrey, lodgepole, shore, and knobcone pine. In ponderosa pine, the

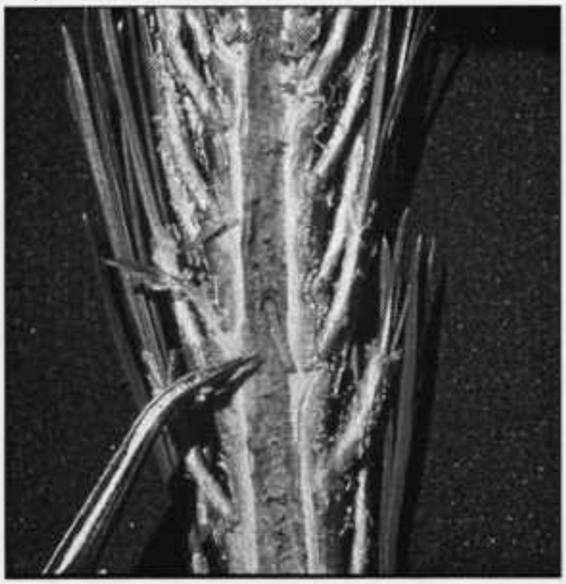
Table 2.—Shoot- and twig-feeding insects of Oregon trees. Insect groups marked in bold are discussed in text.

Tree species	Aphids	Beetles	Borers	Midges	Moths	Weevils
Conifers						
Cedar						
Alaska-		x				
Incense-		x	x		x	
Port-Orford-		x			x	
Western red						
Fir						
Douglas-	x	**X**	x		**X**	**X**
Grand/White	**X**	x	x		**X**	x
Noble	**X**				**X**	
Pacific silver	**X**	x			**X**	x
Shasta red	**X**					
Subalpine	**X**	x			**X**	
Hemlock						
Mountain		x	x		x	
Western	x				x	
Juniper		x				
Larch	x				x	
Pine						
Jeffrey	x	x	**X**		**X**	x
Knobcone		x	**X**		x	x
Limber		x				
Lodgepole	x	x	**X**		**X**	x
Ponderosa	x	x	**X**	**X**	**X**	x
Sugar	x	x	x		**X**	
Western white	x	x				
Whitebark		x				
Redwood		x	x		x	
Spruce						
Brewer						
Engelmann	x				x	**X**
Sitka	x	x			x	**X**
Yew						

Table 2.—Shoot- and twig-feeding insects of Oregon trees (continued).

Tree species	Beetles	Borers	Moths	Scales	Weevils
Hardwoods					
Alder	x	x			x
Ash					
Aspen			x		
Birch		x			
Buckthorn	x				
Cherry					
Chinkapin		x			
Cottonwood					
Dogwood					
Madrone	x		x		
Maple		x			
Myrtlewood	x	x			
Oak	x	x		X	
Tanoak					
Willow	x	x			x

Figure 14.—Western pineshoot borer damage.



infested terminals usually are stunted but survive, while infested lateral shoots usually die. In lodgepole pine, death of the infested leader is common. The most significant damage occurs in eastern Oregon. Each attack reduces height growth by 25 percent.

Midges

The most important twig and shoot midge occurs on ponderosa pine and is called the **gouty pitch midge** (*Cecidomyia piniinopis*). It frequently infests open-grown ponderosa pine, where old damage appears as scattered dead branch tips or flags. Heavy pitch midge infestations retard tree growth, cause branch deformities, and damage tree form. Eggs are laid on new shoots in the spring and hatch into minute red larvae that bore into the vascular tissue, creating pitch pockets.

Moths

Moths get their name from the adult, but it is the larvae that damage shoots and twigs. The most important stem- and twig-feeding moths in Oregon are the ponderosa pine tip moth and the fir coneworm.

The **ponderosa pine tip moth** (*Rhyacionia zozana*) attacks open-grown ponderosa pine seedlings and occasionally lodgepole, sugar, and Jeffrey pine. Repeated attacks on seedlings result in growth loss and stem deformities. There is one generation per year. During the summer, the orange larvae of this insect can be found boring in the shoot tips of infested pine.

The **fir coneworm** (*Dioryctria abietivorella*) is very destructive of cones and shoots of true firs and Douglas-fir in Oregon. The larvae bore into the cambium of the trunk, branches, shoots, and cones. Feeding on Douglas-fir terminal shoots in May and June can sever the stem or result in distorted growth. The larvae pupate and hatch into bluish-gray moths that measure about ½ inch long.

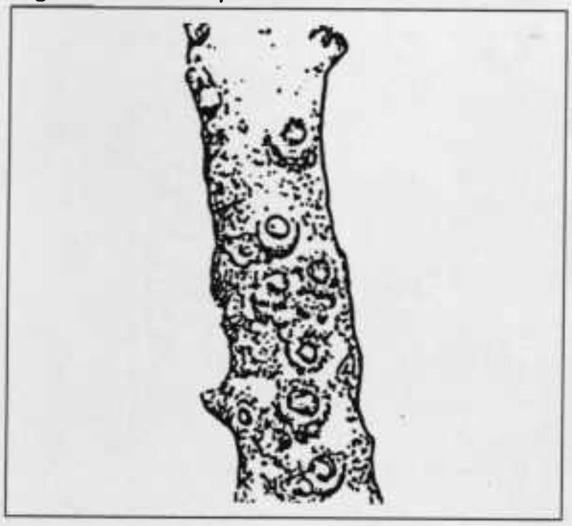
Scale

The **oak pit scale** (*Asterolecanidae*) is an introduced insect that is a serious pest of Oregon white oak. The adult scale is only ¹⁄₁₆ inch in diameter and appears as a thin brown to dull green plate surrounded by a ring of swollen bark (Figure 15). The pits are observed most easily on 2- or 3-year old branches. Badly infested trees have dead branches, thin crowns, and a proliferation of adventitious growth (new leaf growth on boles).

Weevils

Adult weevils are recognized by a snout-like downward-curved extension of the head. Important shoot- and twig-feeding weevils in Oregon are the white pine weevil and the Douglas-fir twig weevil.

Figure 15.—Oak pit scale.



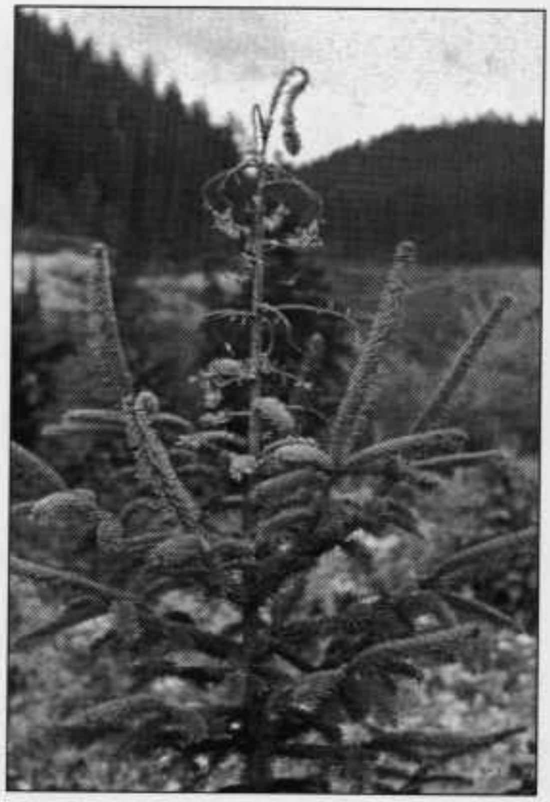
The **white pine weevil** (*Pissodes strobi*), which locally is called the Sitka spruce weevil, is the most important pest of Sitka spruce in Oregon. It limits the commercial production of Sitka spruce in areas more than 1.5 miles from the coast. The weevil also attacks Engelmann and ornamental spruces. Curiously, white pines in the west are not affected. Repeated weevil attacks slow growth and produce severe stem deformations.

From April to June, adult weevils are present on terminals. Eggs are laid in the terminal shoot during May and June. Damage is noticed first in the summer, when terminals suddenly yellow and lose their needles. In July, the leader starts to wilt as larvae feed in the inner bark (Figure 16).

Larvae excavate chip cocoons (pupation chambers) in the wood. From August to September, leaders turn red, and new adults bore out through the bark and overwinter in the duff.

The **Douglas-fir twig weevil** (*Cylindrocopturus furnissi*) is a minor pest of young, open-grown Douglas-fir in western Oregon. The weevil is a problem mainly during drought years or on stressed sites.

Figure 16.—White pine weevil damage on Sitka spruce.



Twig weevil damage appears as scattered dying of young branches and the tops of trees. On older trees, damage is concentrated on laterals with 2-year-old growth.

Adult weevils most commonly are found on trees from June to August. From August to June, the immature stages of the weevil can be found under the twig bark near where the dead twig joins the live branch. In winter, they bore into the pith.

Ecologic roles of shoot- and twig-feeding insects

As with foliage-feeding insects, shoot- and twig-feeding insects traditionally were thought to be pests to be eradicated. Like defoliators, they can and have caused tremendous economic damage to Oregon's forests. Exotic introductions such as the balsam woolly adelgid lack the environmental restraints that limit severe epidemics in their native range.

The beneficial roles of native shoot- and twig-feeding insects in forested ecosystems are just beginning to be studied and accepted. Shoot- and twig-feeding insects are a source of food for other wildlife. However, unlike foliage-feeding insects, shoot- and twig-feeders often live under the bark or within the pith and therefore are not as accessible to birds and rodents.

Shoot- and twig-feeding insects also recycle nutrients in foliage and twigs back to the forest floor as dead foliage, twigs, and insect frass. The dead twigs and deformed branches provide a special niche for wildlife that normal, healthy branches do not.

Almost no research has been conducted on environmental conditions that favor "problem" situations with shoot- and twig-feeding insects in Oregon. It has been observed that the fastest growing trees, such as those in open-grown plantations, are more susceptible to attack by the western pineshoot borer and the white pine weevil. Trees in understory situations that are growing more slowly seldom are attacked by these pests. The exact reasons for this phenomenon are unknown.

Management of shoot- and twig-feeding insects

In some cases, shoot-infesting insects attack healthy, fast-growing trees planted on appropriate sites. As with defoliating insects, management or control of shoot- and twig-feeding insects depends on the management objectives for the forest.

Direct control of shoot- and twig-feeding insects with insecticides has not been as effective nor as warranted as it is for foliage-feeding insects. For this reason, indirect control is more effective. Some indirect control measures are as follows:

- Favoring resistant tree species is recommended for balsam woolly adelgid and white pine weevil.
- Planting Sitka spruce trees close together stimulates height growth, has a beneficial effect on tree form, and creates a less favorable environment for white pine weevils.
- Growing spruce or ponderosa pine in the understory (uneven-age management) reduces damage from shoot borers and weevils. However, the reduction in height growth due to suppression must be weighed against the reduction in height growth that insects might cause.
- Maintaining tree vigor reduces damage from twig beetles and weevils. Mating disruption using synthetic pheromones reduces shoot infestations by the western pineshoot borer by 70–80 percent in the year of application.
- If terminal branches are killed, all but the best lateral branch can be pruned to form a new leader.

Trunk- and Large-branch-feeding Insects

CHAPTER 4

The most important trunk- and large-branch-feeding insects in Oregon forests are aphids, pitch moths, flatheaded borers, and bark beetles. Bark beetles are the most damaging of this group.

Aphids

Several species of aphids feed on stems and branches of Oregon firs, hemlocks, and willows (Table 3), but only the balsam woolly adelgid (see Chapter 3) is economically important.

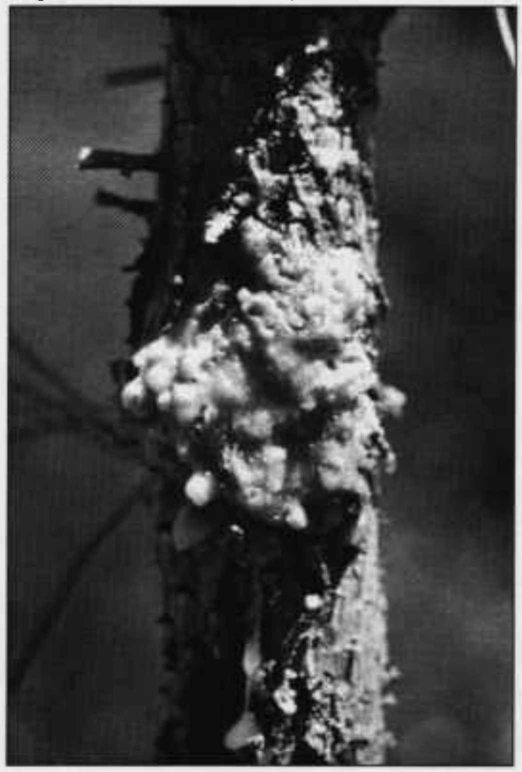
Pitch moths

Pitch moths are named because of the copious amounts of pitch that are produced by infested trees (Figure 17). There are two important pitch moths in Oregon: the sequoia pitch moth and the Douglas-fir pitch moth.

The **sequoia pitch moth** (*Synanthedon sequoiae*) infests ponderosa, lodgepole, shore, sugar, and many ornamental pines in Oregon. Wounds created by the larvae can degrade the wood. Attacks on large trees are not damaging, but on infested small trees, wind breakage of wounded limbs can occur.

Pitch moths often are associated with pruning wounds. Wounds can be reinfested for several years. The adult moths are unusual in that they mimic yellow jackets and fly during the day. They lay eggs in bark crevices or wounds from July to August. Larvae bore into the cambial area, where they feed for 1 or 2 years. Larvae pupate near the surface of the pitch mass, where empty pupal cases often are found.

Figure 17.—Pitch from pitch moth infestation.



The **Douglas-fir pitch moth** (*Synanthedon novaroensis*) is similar to the sequoia pitch moth except that it attacks Douglas-fir, Sitka spruce, and Engelmann spruce as well as ponderosa and lodgepole pine.

Insecticides have not proven effective in controlling pitch moth attacks. Instead, remove pitch masses and destroy the larvae or pupae. Also, avoid wounding trees or pruning branches in the spring or summer. Prune between October and February for fewer attacks.

Flatheaded borers

Two species of flatheaded borers in Oregon infest the cambial area of conifers much as bark beetles do. Sapling-size trees and larger can be susceptible to

Table 3.—Trunk- and large-branch-feeding insects of Oregon trees. Insect groups marked in bold are discussed in text.

Tree species	Aphids	Bark beetles	Flatheaded borers	Moths
Conifers				
Cedar				
Alaska-		x		
Incense-		**X**		x
Port-Orford-		**X**		
Western red		x		
Fir				
Douglas-	x	**X**	**X**	**X**
Grand/White	**X**	**X**	**X**	
Noble	x	x	**X**	
Pacific silver	**X**	x	**X**	
Shasta red		**X**		
Subalpine	**X**	x		
Hemlock				
Mountain		x		
Western	x	x	**X**	x
Juniper		x		
Larch		**X**		x
Pine				
Jeffrey		x	**X**	
Knobcone		x		
Limber		x		
Lodgepole		**X**		**X**
Ponderosa		**X**	**X**	**X**
Sugar		**X**	**X**	**X**
Western white		**X**		x
Whitebark		**X**		
Redwood		x		x
Spruce				
Brewer				
Engelmann		**X**	**X**	**X**
Sitka		**X**	**X**	**X**
Yew				

Table 3.—Trunk- and large-branch-feeding insects of Oregon trees (continued).

Tree species	Aphids	Bark beetles	Borers	Moths
Hardwoods				
Alder		x	x	x
Ash		x		x
Aspen		x		x
Birch		x	x	
Buckthorn				
Cherry		x		
Chinkapin				
Cottonwood			x	x
Dogwood				
Madrone		x	x	
Maple				
Myrtlewood		x		
Oak		x	x	x
Tanoak		x		
Willow	x	x	x	x

borer infestations. Infestations are common on harsh sites or in areas where other factors such as disease, defoliation, or fire have weakened trees. Sometimes borer attacks kill individual branches or portions of a tree's crown.

The **flatheaded fir borer** (*Melanophila drummondi*) infests Douglas-fir, true firs, spruce, and western hemlock. In spring, the female beetle lays eggs in bark crevices, and the larvae bore in the inner bark, making broad irregular galleries (Figure 18). There are no external signs of borer attacks such as boring dust or pitch tubes. It is difficult to detect borer attacks before the tree's crown yellows.

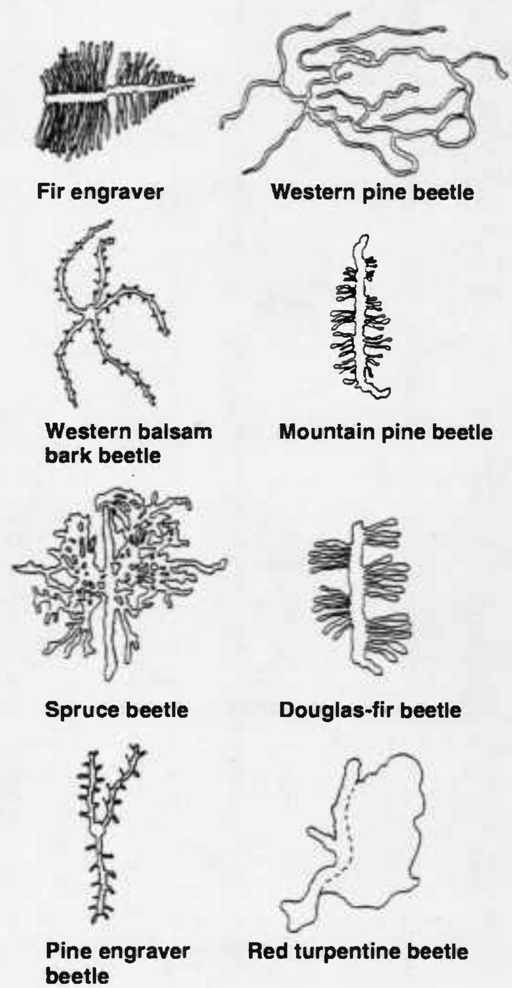
In southwest Oregon, the **California flatheaded borer** (*Melanophila californica*) commonly attacks Jeffrey and ponderosa pine growing on harsh sites. Flatheaded borer infestations often occur in association with pine bark beetles. The biology and appearance of the California flatheaded borer is similar to that of the flatheaded fir borer.

Figure 18.—Flatheaded borer galleries and larvae.

Bark beetles

Bark beetles are by far the most important forest tree insect pests in Oregon. All Oregon tree species, except yew and several hardwood species, are attacked by bark beetles (Table 3). The most damaging bark beetles, however, infest firs, pines, and spruces. These pests include the mountain pine beetle, western pine beetle, pine engraver beetle, red turpentine beetle, fir engraver beetle, Douglas-fir beetle, and spruce beetle. Several bark beetle species attack young trees or the crowns of mature trees, and often are identified by their distinctive gallery patterns (Figure 19).

Figure 19.—Bark beetle gallery patterns.



The **mountain pine beetle** (*Dendroctonus ponderosae*) is one of the most destructive bark beetles in Oregon. The beetle causes severe mortality in lodgepole, ponderosa, western white, sugar, and whitebark pine. Lodgepole pines that are more than 6 inches d.b.h. and more than 80 years old and growing in dense stands are most susceptible. Young ponderosa pines (at least 6 inches d.b.h.) are susceptible if in dense stands. The threat of beetle infestation in older, unmanaged pine stands is great enough to influence forest management decisions in much of eastern Oregon.

The beetle carries spores of a blue-stain fungus that infects the sapwood and colors it blue (Figure 20). The blue stain may help kill the tree and make it more suitable for the beetles. Blue stain does not weaken or decay wood but increases the cost of pulping the wood and causes a lower lumber grade. On the other hand, blue-stained wood often is sold for specialty interior paneling and furniture.

Adult beetles attack trees in July and August, sometimes leaving a pitch tube or bubble where each beetle enters the bark (Figure 21). Dry boring dust also may appear in the bark crevices below the pitch tubes. Adult beetles form a vertical gallery in the inner bark and deposit eggs that hatch into larvae. Larvae form horizontal galleries.

From May to July of the year after attack, infested trees turn red. The larvae pupate and form adults that emerge from infested trees in July.

The **western pine beetle** (*Dendroctonus brevicomis*) is an important cause of mortality in second- and old-growth ponderosa pine. The beetle often is associated with trees weakened by drought, root disease, soil compaction, or mechanical damage. The western pine beetle often is associated with other species of bark beetles attacking the same tree. The

Figure 20.—Blue stain in lodgepole pine.

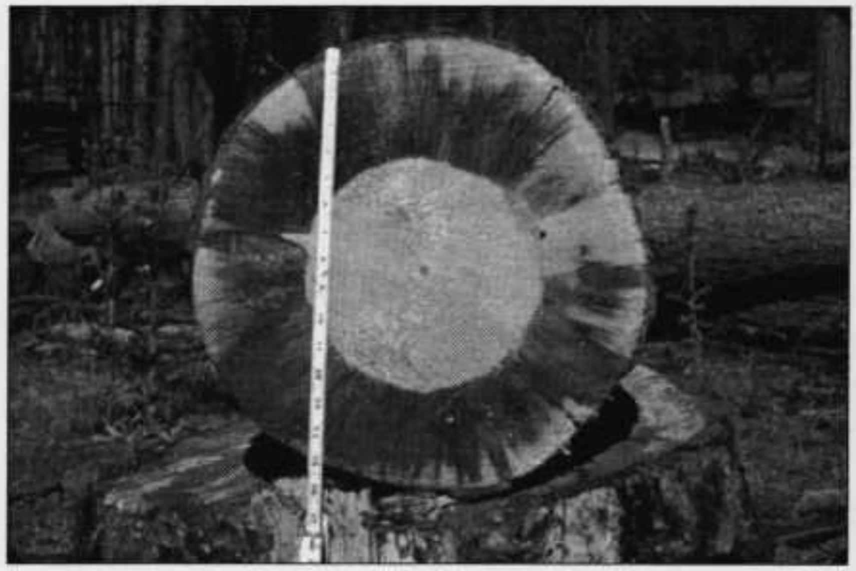


Figure 21.—Pitch tubes on ponderosa pine.

western pine beetle has two generations per year in most of Oregon except in the southwest, where three generations per year are common.

The first sign of attack, months before any change in foliage color, is the appearance of small pitch tubes on the outer bark. Pitch tubes consist of white to red-brown masses of resin that often are associated with fine boring dust collected in bark crevices. Attacks are confirmed by removing the bark from dying trees to expose the winding, crisscrossing egg galleries that resemble "chicken wire" (Figure 19). The sapwood of infested trees is blue-stained from fungal infection.

The **red turpentine beetle** (*Dendroctonus valens*) also attacks pines stressed by drought or other factors. It attacks ponderosa, sugar, western white, lodgepole, and many ornamental pines in Oregon. Attacks are concentrated on the lower trunk or root collar of infested pines. Infested trees are attacked at the same time in the upper bole by other species of bark beetles. Trees usually are not killed unless infested by other species of beetles. There is only one generation per year in most of Oregon except in the southwest, where two generations are possible.

Large pitch tubes on the bark usually are the first sign of attack. If you remove the bark, you may be able to see the adult beetles (the largest in Oregon) or the larvae. Adult beetles can be found between May and September.

The **pine engraver beetle** (*Ips pini*) attacks sapling to pole-size pines or the tops of larger trees, especially during drought years. It prefers to infest green slash or wind breakage, but will infest and kill standing green trees when beetle populations are high. In most areas in Oregon, "Ips" have two generations per year. In southwest Oregon, four or five generations per year can occur.

From April to early June, adult beetles infest green slash that is 2 to 8 inches in diameter. Orange-brown boring dust in the bark crevices of the slash is the first sign of activity. From June to August, new adult beetles leave the slash and can infest standing live trees if there is not a fresh supply of green slash. Adult galleries are "Y" or "H" shaped (Figure 19).

The **fir engraver beetle** (*Scolytus ventralis*) is a significant cause of mortality of grand, white, and Shasta red fir in Oregon. It also can be found on Douglas-fir and Engelmann spruce. Fir engraver beetles breed in logging slash and may attack adjacent standing green trees, especially if trees are stressed by drought, defoliation, root disease, or overstocking. The fir engraver beetle has one generation per year.

If mortality does not occur, beetle attacks often result in patch kills where only a portion of the trunk is killed. This causes a wound that may become infected with fungi, resulting in stain, ring-shake, or decay.

From June to September, adult beetles bore into firs, often causing a stream of pitch at the entrance hole. Brown boring dust often collects in bark crevices. Fir engraver attacks can be confirmed by removing a patch of bark and finding the beetle or its distinctive horizontal adult gallery (Figure 22). Larval galleries are vertical above and below the adult gallery.

From September to June, individual branches, tree tops, or entire trees turn yellow-green and eventually red. Adult beetles carry a brown-stain fungus that helps kill the tree.

The **Douglas-fir beetle** (*Dendroctonus pseudotsugae*) is one of the most important causes of Douglas-fir mortality in both western and eastern Oregon. Western larch also can be attacked, but only if trees are extremely weakened or windthrown.

Beetles introduce a brown-stain into the sapwood.

In western Oregon, attack is associated with windthrown Douglas-fir or root disease. One to 2 years after windthrow, beetle populations increase to a level where nearby green standing trees are attacked. In eastern Oregon, attack often is associated with defoliation from the western spruce budworm or the Douglas-fir tussock moth.

From April to June, reddish or yellowish boring dust is the first sign of beetle attack. When standing trees are attacked, boring dust is found in bark crevices or at tree bases. Streams of resin may be visible at the mid- to upper boles where attacks have occurred. Removing the bark of infested trees reveals the beetle, larvae, or their galleries (Figures 23 and 24). In eastern Oregon, trees attacked the previous year turn red in the spring. From July to October, about half of the attacked trees in western Oregon fade from green to yellow and eventually to red. The remainder fade the next spring.

The **spruce beetle** (*Dendroctonus rufipennis*) is the primary pest of mature Engelmann spruce in eastern Oregon. Sitka spruce also is attacked. Most outbreaks occur when beetles breed in windthrow and attack adjacent green trees. High hazard trees are those greater than 16 inches d.b.h. growing in stands with a spruce component of 65 percent or more.

Figure 22.—Fir engraver galleries.

Figure 23.—Douglas-fir beetle galleries.

Figure 24.—Douglas-fir beetle adult and eggs.

Adult beetles emerge from May to October to attack windthrown trees. During the first summer of attack, piles of boring dust in bark crevices or around tree bases are the first signs of attack. Adult beetle galleries run parallel to the wood grain; larval galleries radiate to the sides.

From fall to winter, trees still are green, but woodpeckers may partially debark the bole in search of beetle larvae. During the second summer following attack, spruce needles turn yellow and then red.

Some bark beetles often infest young trees or the crowns of mature trees. Two of the most common beetles in this category, the pine engraver and fir engraver, were discussed on page 28. Another engraver beetle, the **California five spined ips** (*Ips paraconfusus*), infests ponderosa, sugar, and western white pine in southern Oregon. This beetle has two to three generations per year and an appearance and life cycle similar to that of the pine engraver beetle.

Young Douglas-fir or the crowns of mature trees under environmental stress often are infested by either the **Douglas-fir pole beetle** (*Pseudohylesinus nebulosus*) or **Douglas-fir engraver beetle** (*Scolytus unispinosus*). Both of these bark beetles have one generation per year.

The branches and crowns of stressed or low-vigor incense-cedar often are infested by the **cedar bark beetle** (*Phloeosinus* sp.). These beetles are abundant in southern Oregon. They become evident during droughts and may have more than one generation per year on warmer sites. These beetles also infest Port-Orford-cedar trees that have been affected by Port-Orford-cedar root disease.

Ecologic roles of trunk- and large-branch-feeding insects

As with many forest insects, trunk and large-branch-feeding insects, especially bark beetles, traditionally were thought of as serious pests to be controlled. Bark beetle-caused mortality has caused tremendous economic damage to Oregon's forests. These insects' beneficial roles in forested ecosystems are just beginning to be studied and accepted.

Bark beetles serve as a source of food for wildlife, especially birds. In fact, an obvious sign of bark beetle attack is the partial bark removal caused by larvae-foraging birds.

Another important role of trunk- and large branch insects is their ability to recycle nutrients of entire trees back to the forest floor. This function is especially important when forest stands are overstocked and soil nutrients become scarce. Following defoliator outbreaks, bark beetles kill millions of overstocked fir trees during an epidemic. The surviving trees of other species such as pines benefit from the newly created growing space and the nutrients from dead needles, branches, trunks, and roots.

Bark beetles play an important role in forest succession. For some species, such as westside Douglas-fir, bark beetles and their associated root diseases are the only biological agent that results in mortality. Gaps created in the canopy by beetle-caused mortality allow other tree species such as hemlock and cedar to become dominant.

In lieu of periodic low-intensity fires, bark beetles are natural thinning agents, attacking and killing the largest trees first. Beetle-killed stands are at high risk of catastrophic wildfire, a quick and efficient nutrient recycler.

Much research has been conducted regarding the site and stand conditions that favor the development of "problem" situations with bark beetles. For example, fire exclusion policies initiated at the turn of the century resulted not only in an unprecedented abundance of true firs and Douglas-fir, especially in eastern and southern Oregon, but also an overstocking of other species on their sites.

Firs defoliated by western spruce budworm or tussock moth in eastern Oregon subsequently are attacked by either Douglas-fir beetles or fir engravers. In western and southern Oregon, drought-affected stands are attacked by Douglas-fir beetles and flatheaded fir borers.

Overstocked stands of lodgepole pine are attacked by mountain pine beetles. Dense stands of ponderosa pine are attacked by either western pine beetles, mountain pine beetles, pine engravers, or all three.

Management of bark beetles

The following strategies may help prevent or reduce bark beetle-caused mortality.

Maintain tree vigor

All species of bark beetles prefer to attack and may kill trees that are weakened by other causes such as drought or defoliation. You can minimize the detrimental effects of many of these weakening factors by thinning or spacing trees to provide growing room, sufficient nutrients, and water.

Maintain mixtures of tree species

Growing mixtures of tree species is good management for many insect and disease problems, including bark beetles, which usually are species specific. For example, Douglas-fir beetles attack and kill Douglas-fir but not pine or spruce. Growing a mixture of tree species ensures the increased survival of those species not attacked by bark beetles. When mixing pine with other conifer species, follow the density guidelines for pine; in overstocked stands with a pine component, pines often are attacked before the other species.

Remove or destroy infested trees before beetles emerge

Bark beetle populations can be reduced if infested trees are harvested or destroyed (burned) before beetles emerge. This removal must be done in the spring. Exact timing depends on beetle species. There are at least two limitations to this technique. Timing is critical to remove all of the infected trees before the beetles emerge, and timing may change depending on the weather. The technique is effective only over large areas such as watersheds; beetles are strong fliers and can invade from long distances.

Salvage or treat windthrown trees

Removal of windthrown trees before the next spring for Douglas-fir beetle or within 1 year for the spruce beetle prevents population buildup on down trees and subsequent attacks on standing green trees. If a large blowdown of Douglas-fir occurs between August and February and cannot be salvaged, it is possible to treat down logs with an aerial application of an anti-aggregative pheromone (beetle repellent). This technique prevents the beetles from breeding in down logs and keeps beetle populations from increasing to a level at which green trees are attacked. Beetle-repellent techniques are relatively new, and a special-use permit is required.

Create logging or thinning slash only in late summer and fall

Thin white fir or pine stands from August to December when bark beetles are not flying. Material less than 3 inches in diameter can be thinned anytime, however, because small branches and stems do not afford a large enough breeding area to produce large beetle populations.

If you must create slash between January and June, and the operation involves large acreage, a technique called the "green chain" may help avoid damage to leave trees. This technique involves creating new slash at 2-week intervals or continuously during July and August. The new slash, which Ips prefer to attack, soaks up the beetles as they emerge from the slash created between January and June. If fresh slash is not available in July and August, attacks on green trees may occur. During severe fire danger periods in the summer, woodsworkers may not have access to the forest to perform these treatments.

Treat slash to make it unsuitable for beetles

Treat logging or thinning residues to make them unattractive to bark beetles, especially the pine and fir engravers. Cull logs and tops should be limbed, cut into short lengths, and left exposed to sunlight. This treatment of slash facilitates rapid drying and makes the material unsuitable for beetle reproduction. Leave large slash in the sun to dry, and do not leave it around the bases of green trees. Piling of slash is not recommended until the slash has dried sufficiently to no longer be suitable for engraver beetles.

Avoid cutting firewood from newly infested trees

If firewood is cut in May and June from pines that have yellow crowns, adult beetles may emerge from the logs to attack standing green trees. Store such logs away from green trees and cover the logs with plastic to kill the emerging beetles.

Use chemical sprays or pheromones on high-value trees

Individual high-value trees may be sprayed with insecticide to protect the trees from beetles. Spray before beetle flight, which occurs from April–June. A 2-percent active ingredient solution of carbaryl (Sevin) sprayed to runoff on the trunk is an effective preventive treatment. Spray insecticides from the tree base (for turpentine beetles) to as far up the trunk as possible and to a height of at least 30 feet. Applications may have to be repeated annually. Trunk sprays are not registered for forest use.

Plastic-encased pheromones called bubble-caps can be attached to high-value green Douglas-fir trees to make them less attractive to beetle attack. This "beetle repellent" prevents beetles from attacking and killing treated trees. A special-use permit is required.

Root-feeding Insects

The most important root-feeding insects in Oregon forests are beetles and weevils (Table 4). These insects are important not only for the damage they cause by feeding, but for a fungus they introduce into the root system that results in black stain root disease (Figure 25). Douglas-fir, pine, and hemlock are the known hosts in Oregon.

The vectors (carriers) of this disease in Douglas-fir are the bark beetle *Hylastes nigrinus* and two species of weevils, *Pissodes fasciatus* and *Steremnius carinatus* (Figure 26). The bark beetle *Hylastes macer* may be a vector of black stain root disease of ponderosa pine. Once established by the insects, black stain root disease spreads from root to root on its own without further need for insect vectors.

Root-feeding bark beetles

Root-feeding bark beetles (*Hylastes* spp.) are most successful in attacking Douglas-fir whose roots are injured or stressed from logging injury, road building, soil compaction, or thinning shock. The beetles carry the spores of the black stain root disease fungus (*Leptographium wageneri*).

Adult beetles burrow through the soil to roots in the spring and may feed on wounded roots of several trees or stumps before they construct galleries. This feeding may result in introduction of the fungus.

Beetle populations increase dramatically in young Douglas-fir that are thinned between September and May. Because the main beetle flight in Oregon is in May, stands thinned before June are readily attacked by emerging beetles. Thinning slash and stumps thinned after August still are fresh at this time and may be attacked in the spring. Although *Hylastes macer* is thought to spread black stain root disease in ponderosa pine, its role as a disease vector in Douglas-fir is not as well known as that of *Hylastes nigrinus*.

Root- and root-collar-feeding weevils

There are two species of **root- and root collar-feeding weevils** that spread black stain root disease of Douglas-fir: *Pissodes fasciatus* and *Steremnius carinatus*. Their life cycles take 1–2 years and they spread fungal spores much as the root-feeding

Figure 25.—Black stain in an infected ponderosa pine.

Figure 26.—Beetles and weevils that spread black stain.

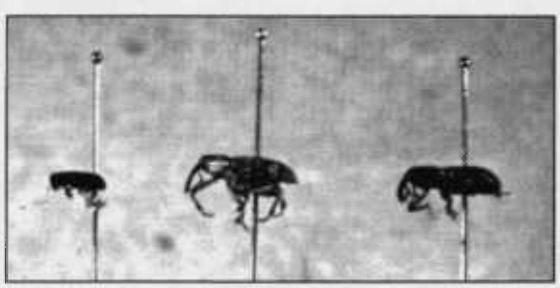


Table 4.—Root-feeding insects of Oregon trees. Insect groups marked in bold are discussed in text.

Tree species	Beetles	Weevils
Conifers		
Cedar		
Alaska-		
Incense-		
Port-Orford-		
Western red		x
Fir		
Douglas-	**X**	**X**
Grand/White	x	
Noble		x
Pacific silver		
Shasta red		x
Subalpine		
Hemlock		
Mountain	x	x
Western	x	x
Juniper		
Larch		
Pine		
Jeffrey	x	x
Knobcone		x
Limber		
Lodgepole	**X**	**X**
Ponderosa	**X**	**X**
Sugar	x	
Western white	x	x
Whitebark		
Redwood		
Spruce		x
Brewer		
Engelmann	x	
Sitka		
Yew		

Table 4.—Root-feeding insects of Oregon trees (continued).

Tree species	Beetles	Weevils
Hardwoods		
Alder		
Ash		
Aspen		
Birch		
Buckthorn		
Cherry		
Chinkapin		
Cottonwood		
Dogwood		
Madrone		
Maple		x
Myrtlewood		
Oak	x	
Tanoak		
Willow	x	

bark beetles do. *Pissodes* can fly, whereas *Steremnius* is flightless but can walk up to 500 feet in 7 weeks. Both weevils breed in freshly cut stumps and can be very abundant 2 years after harvest or thinning operations.

Steremnius also is called a conifer seedling weevil because its maturation feeding frequently girdles and kills small-diameter Douglas-fir seedlings. Seedling damage, particularly to plugs, occurs shortly after planting in areas that lack herbaceous vegetation. Larger diameter Douglas-fir seedlings are not damaged significantly by weevil feeding.

Pissodes fasciatus is related to the white pine weevil (*Pissodes strobi*), which kills the leaders of spruce. Like the white pine weevil, *Pissodes fasciatus* larvae form chip cocoons. In this case, the cocoons are found in the inner bark of infested root collars and boles.

Ecologic roles of root-feeding insects

As with other insects that cause tree mortality, root-feeding insects and the disease fungus they carry convert living biomass to dead biomass and create snags and down woody debris. As a result, they help release nutrients. Because black stain root disease is fairly species-specific, other tree species and plants take advantage of the spaces left by the dead host trees. Pure stands of either infested Douglas-fir or ponderosa pine eventually become mixed species stands as nonsusceptible plants fill in the gaps left by the dead trees.

Areas with black stain root disease commonly occur along roadsides, in stands that have been thinned, and in stands with a history of soil disturbance from tractor logging. The insect vectors are attracted to volatile chemicals emitted from the damaged trees or stumps.

Management of root-feeding insects

Management of root-feeding insects also reduces the establishment of black stain root disease. If black stain already exists on a site, other tree species should be favored or planted. For instance, if Douglas-fir is affected, hemlock, cedar, or alder should be favored. If ponderosa pine is infested, white fir or Douglas-fir should be favored. The disease does not spread from ponderosa pine to Douglas-fir because there are two different strains of the fungus, one on Douglas-fir and one on pine and hemlock.

The potential for establishing new black stain root disease centers can be minimized by reducing site disturbance and tree injury. In high-hazard areas (areas within a mile of known disease centers), tractor logging should not be used as a harvest system; instead, use systems that minimize soil compaction and root wounding such as horse logging or light cable systems. Favor mixed species in areas of highest risk. Avoid activities that result in tree wounding. Complete precommercial thinning between June and early August after the main flight of the beetles.

Effects of Forest Practices on Insects

Precommercial thinning

Precommercial thinning (PCT) has been practiced for many years in Oregon. There are advantages and disadvantages to precommercial thinning in terms of effects on forest insects but few have been scientifically tested. Advantages are as follows:

- Wounded and infested trees can be eliminated.
- Excellent growth response results if live crown ratios and previous height growth are good.
- Shorter rotation ages can be used.
- Insect-tolerant species can be favored.
- Residual trees are more resistant to certain insects because of increased vigor.

Some disadvantages of PCT include:

- Sunscalding can occur on some species (true firs) on certain sites if spacing is too wide.
- Slash creation increases risk from fire, stem-wounding, and bark beetle attack.
- Stumps may become infested by root-feeding bark beetles, vectors of black stain root disease.
- Residual trees are more susceptible to certain insects because of increased vigor.

Precommercial thinning of overstocked ponderosa and lodgepole pine stands can prevent outbreaks of mountain pine beetles and pine engraver beetles. Thinning slash must be properly disposed of to prevent attack by pine engravers. In eastern Oregon, precommercial thinning has been shown to increase radial growth of grand fir that is lightly to moderately defoliated by the western spruce budworm, especially if trees also are fertilized with urea.

Commercial thinning, seed tree harvesting, and shelterwood harvesting

The effects of commercial thinning, seed tree harvesting, or shelterwood systems on insect populations and damage have been documented in the interior west. The advantages and disadvantages of precommercial thinning also apply to commercial thinning. In eastern Oregon, studies have shown that thinning can increase vigor and resistance of lodgepole pine and ponderosa pine to mountain pine beetle. The increased distance between trees may affect insect response to pheromones, and the altered microclimate also may affect beetle movement in thinned stands.

Sanitation-salvage harvesting

The term "sanitation-salvage" harvesting or cutting is a combination of several closely related terms. *Salvage cuttings* are made for the chief purpose of harvesting trees that have been or are in imminent danger of being killed or damaged by agents other than competition between trees. *Sanitation cuttings* involve the removal of trees that have been attacked or appear in imminent danger of attack by pests to prevent spread from one tree to another.

These operations are not necessarily confined to the removal of merchantable trees. Sanitation-salvage harvesting therefore is the removal of dead and dying trees to recover economic value that otherwise would be lost as a result of mortality from some pest.

There are several economic benefits to sanitation-salvage harvesting as it relates to forest resources, especially, but not necessarily only, to timber values:

- Sanitation-salvage harvesting reduces fire hazard by removing dead and dying trees.
- Stands can be regenerated to a more healthy condition.
- Infested and high-risk trees are removed.
- The economic value of dead and dying trees is captured.

Several classifications have been developed to guide tree marking during sanitation-salvage harvesting. These classifications relate to the risk of attack by insects or disease pathogens. In 1960, a classification for ponderosa pine in the Pacific Northwest was developed that uses crown size and form to predict attack from western pine beetle. Similar risk-rating systems based on crown form have been developed for fir engraver beetles in white and Shasta red fir. The most severe ratings have been shown to indicate a likelihood of reduced tree growth and can be a guide for decisions concerning tree removal.

Entering stands, including for sanitation-salvage harvesting, can increase mortality due to root diseases, especially annosus root disease. Infection by the annosus root disease fungus, *Heterobasidion annosum*, occurs when living trees are harvested with dead trees, because spores require freshly exposed living wood, such as a freshly cut stump or fresh trunk wound, to germinate and infect. In forests with repeated defoliation, many trees believed to be killed and thus marked for removal actually are still alive, and the freshly cut stumps are ideal infection courts for windblown spores of *H. annosum*. True firs are especially susceptible.

Clearcutting and regeneration

For pest management, clearcutting usually presents fewer problems than other types of harvesting because it leaves no residual trees to be windthrown, to infest regeneration, or to damage regeneration when they are removed later. Nevertheless, susceptible regeneration can become infested with insect defoliators from adjacent border trees or unmerchantable residuals. On the other hand, some insects such as the western pineshoot borer and the white pine weevil are favored by clearcutting; they are most abundant on open-grown fast-growing trees.

In reality, the effect of clearcutting on pest populations and damage is mainly hypothetical in Oregon, and research is needed to determine actual impacts.

The method of regeneration determines the amount of potential pest damage. Planting allows the establishment of pest-resistant species. Natural regeneration may foster the spread of certain insects if susceptible species are allowed to regenerate. Advance regeneration already may be infested with pests before the overstory is harvested; therefore, this method poses the greatest risk of future pest-caused losses.

Uneven-age management

Uneven-age management, in the strict sense, has not been practiced widely in Oregon. Although many forests have an uneven-age appearance, many are "uneven-sized" rather than uneven-aged. This is especially true for shade-tolerant species such as the true firs, where suppressed understory trees may be the same age as their overstory neighbors.

Root diseases, stem decays, dwarf mistletoes, and defoliating insects are affected by stand structure and composition. Silvicultural systems that produce and maintain multistoried stands and climax tree species (especially true fir) generally allow these forest pests to increase. Thus, from a pest management perspective, uneven-age management is more appropriate in ponderosa pine forests than in mixed-conifer forests because fewer pests are associated with pine.

Defoliating insects such as the western spruce budworm and Douglas-fir tussock moth prefer shade-tolerant species such as true fir and Douglas-fir. Multistoried stands are most susceptible for the following reasons:

- The shade-tolerant conifers that are most vulnerable to defoliation are plentiful in the understory.
- A higher percentage of crowns of dominant and codominant trees are exposed to sunlight, creating a more favorable environment for defoliator development.
- Insects can disperse effectively to other hosts in the understory.
- Defoliation increases with the variations in height, diameter, and age of trees.

You can take measures to reduce pest-caused damage in uneven-aged multistoried stands:

- Favor and regenerate nonsusceptible tree species.
- Improve and maintain tree vigor through stocking-level control.
- Reduce tree wounding through well-planned harvesting operations.

Uneven-age management in most cases requires more care than even-age management and may be impractical in severely diseased stands. Nevertheless, it can be effective in many stands to meet land-use objectives while still preventing or reducing the adverse effects of forest pests. More research is needed to determine the short- and long-term effects of uneven-age management in Oregon.

Prescribed burning

Prescribed burning has been used as a silvicultural practice for many years in Oregon. It is used to reduce fuel loads and remove unwanted understory vegetation. The effects of prescribed burning on insects have not been well studied in Oregon, but some studies have been conducted in neighboring areas.

Fire has a direct and obvious effect when insects and their natural enemies are burned. Prescribed burning could decrease several pests, including seed and cone insects, defoliators such as sawflies and pandora moth, and a few other pests, such as the western pineshoot borer, that overwinter on the forest floor. Many insects, including bark beetles and weevils, breed under the bark of logging slash and can be killed by prescribed burning. Most of these insects, however, require fresh slash for a major portion of their life cycle, and burning of old slash accomplishes little in terms of direct pest control.

Prescribed fires also can be used to "thin" stands to increase the vigor of residual trees and reduce infestation rates of bark beetles. In the process, however, other trees are partially burned, and subsequently may be infested with bark beetles or decay fungi.

Fertilizing

Some research regarding the effects of fertilizer on forest insect pests has been reported in Oregon. The most comprehensive study to date was conducted in eastern Oregon to assess the effects of urea fertilizer on western spruce budworm in thinned stands of white fir. This four-part study involved the hand application of urea fertilizer, which significantly increased the weight of budworm. Furthermore, parasitization of late larvae and pupae was reduced significantly in 1 year of the study. Fertilizer treatments, however, resulted in significantly reduced defoliation and significantly heavier biomass of shoot and foliage for the final 3 years of the study. Height and radial growth of fertilized trees was significantly greater than that of unfertilized trees 3–5 years after treatment. Other areas in Oregon with heavier defoliation, however, do not show the same tree growth responses to fertilizers.

Aerial insecticide application

Aerial insecticide applications to manage defoliating insects in the forest have been common in eastern Oregon for many decades. Few studies have been done to determine the long-term effects of aerial insecticide applications on hosts, insects, or natural enemies. A summary report of aerial insecticide treatments for western spruce budworm in Oregon and Washington from 1982 to 1992 showed that 2 years after treatment, defoliation usually returned to pretreatment levels and that defoliation levels in treated and untreated areas were nearly identical.

Another study was conducted in eastern Oregon to determine the effects of treatment with carbaryl on populations of western spruce budworm and growth of host trees. Overall, little difference in the basic pattern of budworm population behavior was apparent between treated and untreated sites. Parasitoid production was reduced temporarily in carbaryl-treated sites, but recovered within 3 seasons after treatment. Host defoliation seemed to be reduced by the carbaryl treatment, but annual ring widths of host trees in treated areas near the study sites did not reveal any growth response.

Some research concerning other insecticides has begun, but results are not yet available. In 1988, several areas in northeastern Oregon were treated aerially with *Bacillus thuringiensis* (BT), a naturally occurring bacterium that reduces defoliator populations. Several formulations of BT significantly reduced defoliator densities when compared to nontreated areas, but long-term effects still are being monitored.

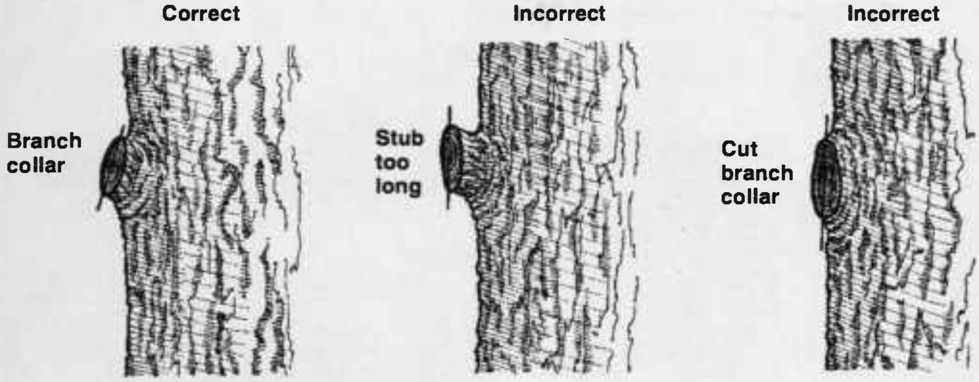
Artificial branch pruning

Artificial pruning of lower crown branches, both living and dead, is used in Oregon to improve wood quality and value. Artificial pruning usually is combined with stand thinning to increase tree growth and sealing of branch stubs.

Advantages of pruning include increased wood quality and value, improved stand access, and removal or prevention of certain disease pathogens. Disadvantages of pruning include increased stem decay, ring shakes, frost and sun cracks, wetwood, cankers, bark and pitch pockets, and insect attack *if done improperly*; reduced tree growth if too many branches are removed; sunscalding of thin-barked species; and formation of epicormic branches (new branches that grow from dormant buds).

Trees have a very effective protection system in the branch corewood, including a protective zone at the base of the

Figure 27.—Proper and improper pruning.



branch. In natural branch pruning, decay fungi spread downward until they reach this zone, and the decay facilitates branch shedding.

The old thought was that longer lengths of clear wood could be obtained by severing the swollen branch collar and cutting branches flush to the trunk. However, a flush cut removes the protective zone at the base of the branch (Figure 27). Although a flush cut stimulates callous formation, the amount of decay may be much worse than with a proper cut, especially in non-resinous species such as true firs or hardwoods. Thus, quality is much worse, not better. On the other hand, improper pruning that leaves stubs may provide dead wood and resources for decay fungi to penetrate the living tree and cause decay.

Sequoia pitch moth and Douglas-fir pitch moth can attack areas around trunk injuries or improperly pruned branches. If branch protection zones are removed, the tissues below the branches are weakened, and the insects take advantage of the situation. The larvae bore into the cambium, causing masses of pitch to form, often with serious damage to young trees.

Conclusions

It generally is much easier to prevent the undesirable feeding activities of forest insects than to control damaging insect populations directly. By integrating forest insect management with forest resource management, the overall health and productivity of Oregon's forests can be improved and maintained.

Many forest practices are used in Oregon, but their long-term effects on forest insects are not well known. We do know, however, that healthy forests can be maintained through intelligent, active forest management that manipulates stand structure and species composition, thus increasing tree vigor and resistance to forest insect pests. Natural enemies of insects and their associated tree pathogens also are influenced by forest practices. The overall result is improved quality of Oregon's natural resources.

References

OSU Extension publications

Aphid and Adelgid Pests of Conifers in Oregon, EC 1444, by J. DeAngelis (1994). 8 pages. 75¢

Biology and Control of Douglas-fir Needle Midge in Christmas Trees, EC 1373, by J. DeAngelis (Revised 1994). 2 pages. 50¢

Forest Disease Ecology and Management in Oregon, Manual 9, by G.M. Filip, A. Kanaskie, and A. Campbell III (1995). 60 pages. $14.50

Forest Health in Eastern Oregon, EC 1413, by P.T. Oester, S.A. Fitzgerald, W.H. Emmingham, A. Campbell III, and G.M. Filip (1992). 6 pages. 75¢

An Introduction to Forest Protection, EC 1253, by A. Campbell III (Reprinted 1992). 12 pages. $1.25

Pacific Northwest Insect Control Handbook, (Revised annually). 364 pages. $25.00

Trees to Know in Oregon, EC 1450, by E.C. Jensen and C.R. Ross (Revised 1994). 128 pages. $4.00

Using Precommercial Thinning to Enhance Woodland Productivity, EC 1189, by P.T. Oester and W.H. Emmingham (Reprinted 1997). 12 pages. $2.00

To order copies of OSU Extension publications, or additional copies of this publication, send the complete title and series number, along with a check or money order for the amount listed (payable to Oregon State University), to:

Publication Orders
Extension & Station Communications
Oregon State University
422 Kerr Administration
Corvallis, OR 97331-2119
Fax: 541-737-0817

We offer discounts on orders of 100 or more copies of a single title. Please call 541-737-2513 for price quotes.

You can access our Publications and Videos catalog and many of our publications on the Web (eesc.orst.edu).

Other publications

Common Insect and Mite Galls of the Pacific Northwest, by H. Larew and J. Capizzi (Oregon State University Press, 1983). 80 pages.

Forest Insect Survey and Control, by J.A. Rudinsky (OSU Book Store, Corvallis). 472 pages.

Western Forest Insects, Miscellaneous Publication No. 1339, by R.L. Furniss and V.M. Carolin (USDA Forest Service, Washington, DC, 1977). 654 pages.

Glossary

Abiotic—Nonliving.

Advance regeneration—Regeneration that occurs before any special measures are undertaken to establish new growth.

Adventitious growth—New leaf growth on the bole of a tree.

Alternate host—An organism that serves as a host for an insect during part of the insect's life cycle. (See also **host**.)

***Bacillus thuringiensis* (Bt)**—A naturally occurring bacterium that occurs in caterpillar populations and leads to their natural decline.

Biological control—Controlling pests through the action of living organisms (whether naturally occurring or brought in by humans) rather than by the application of chemicals. For example, introduced parasites have been successful in controlling the larch casebearer.

Biotic—Living.

Blue stain—A fungus discoloration of sapwood that is spread by bark beetles.

Bole—The main trunk of a tree.

Boring dust—Particles of wood or bark created by insects, especially bark beetles, as they bore into or out of a tree. (See also **frass**.)

Branch collar—The portion of a branch that surrounds the branch as it enters the trunk of a tree. Artificial branch pruning is properly done just to the outside of the branch collar.

Cambium—The thin layer of tissue in a plant that gives rise to new cells and is responsible for secondary growth.

Canker—A sunken and dead area under the bark of a tree stem or branch, usually caused by pathogenic fungi.

Climax species—Those species of trees found in dominant positions in a fully mature forest.

Codominant trees—Trees with crowns forming the general level of the crown cover and receiving full light from above but comparatively little from the sides.

Commercial thinning—Selectively removing trees that have commercial value. (See also **precommercial thinning**.)

Complete metamorphosis—Insect life cycle in which insects change from eggs to larvae to pupae to adults. The larvae are completely different from the adults in appearance and habits. (See also **incomplete metamorphosis**.)

Dominant trees—Trees with crowns extending above the general level of the crown cover and receiving full light from above and partly from the side.

Duff—Forest litter and other organic debris in various stages of decomposition on top of the mineral soil.

Epicormic branch—New branch that grows from a dormant bud.

Flag—A dead branch that still retains its foliage.

Forest succession—The predictable pattern of forest regeneration after a disturbance such as a fire or a clearcut.

Frass—Particles of wood, bark, or foliage created by insects.

Gall—A pronounced localized swelling of greatly modified structure that occurs on plants as a result of irritation by a disease or insect.

Gallery—A passage or burrow excavated by an insect under bark or in wood for feeding or egg-laying purposes.

Genus (pl. **genera**)—A class, kind, or group of organisms marked by one or more characteristics. For example, pine belong to the genus *Pinus*. (See also **species**.)

Gouting—A swelling of bark and wood tissue on a tree stem or branch, usually caused by insects such as aphids.

Green chain—Continuous creation of new slash to attract certain species of bark beetles in order to prevent them from attacking green trees.

Group-selection harvest system—A tree harvesting system designed to create an uneven-aged stand by repeatedly cutting groups or patches of mature trees at short intervals over an indefinite period of time.

Honeydew—A sweet, sticky substance produced by aphids. It attracts ants and is a good medium for sooty mold.

Host—An organism, such as a tree, on or in which a pest is living and from which it is obtaining its food. (See also **alternate host** and **secondary host**.)

Incomplete metamorphosis—Insect life cycle in which the insect changes from egg to nymph to adult. The nymph resembles the adult. (See also **complete metamorphosis**.)

Instar—Stage of larval development.

Lateral branch—A branch on a tree, especially a conifer, that grows laterally from the stem of the tree.

Live crown ratio—The proportion of a living crown height to total tree height, usually expressed as a percentage.

Nonaggressive—Refers to insects, especially bark beetles, that prefer to attack trees that are dead or severely weakened.

Overtopped—See **suppressed**.

Parthenogenic—Reproducing asexually.

Pitch tube—A hardened piece of resin or pitch that forms at the boring holes of insects, especially bark beetles. Pitch tubes indicate an attack on a vigorous tree that exudes pitch as a self-defense mechanism.

Pith—The center portion of a stem or branch.

Precommercial thinning—Removing trees too small to have commercial value in order to achieve better spacing for the rest of the trees in the stand. (See also **commercial thinning**.)

Prescribed burning—The use of regulated fires to reduce or eliminate the unincorporated organic matter of the forest floor or low, undesirable vegetation.

Residual stand—Trees left in a stand after thinning to grow until the next harvest. Also called "reserve stand" or "leave trees."

Ring shakes—Separation of wood along the annual rings between the boundaries of decay or defect columns. Ring shake usually is observed after the tree has been cut and the wood begins to dry.

Salvage cutting—Harvesting trees that have been or are in imminent danger of being killed or damaged by injurious agents other than competition from other trees.

Sanitation cutting—Harvesting trees that have been or appear to be in imminent danger of being attacked by pests, in order to prevent spread of pests from one tree to another.

Sanitation–salvage cutting—See **salvage cutting** and **sanitation cutting**.

Sapwood—The light-colored wood that appears on the outer portion of a cross section of a tree. Composed of dead cells; serves to conduct water and minerals to the crown. Also called **xylem**.

Secondary host—A tree or plant that is infected to a much lesser degree than a primary host.

Seed-tree harvest system—Removal of mature trees in one cutting except for a small number of seed-producing trees left singly or in small groups.

Shelterwood harvest system—Removing mature trees in a series of cuttings over a relatively short portion of the rotation. This practice encourages establishment of essentially even-aged reproduction under the partial shelter of seed trees.

Simple metamorphosis—See **incomplete metamorphosis**.

Slash—Tree tops, branches, bark, and other debris left after a forest operation.

Sooty mold—Black encrustation caused by honeydew from aphids that becomes infected with black fungi or mold.

Sp., Spp.—Abbreviations. Sp. means one species, spp. means two or more species within the genus named.

Species—A subcategory of organisms with one or more characteristics in common. For example, a species of pine is lodgepole pine, *Pinus contorta*. (See also **genus**.)

Sunscald—Death of cambial tissue on one side of a tree, caused by exposure to direct sunlight.

Suppressed trees—Trees with crowns entirely below the general level of the overstory cover, receiving no direct light either from above or from the sides. Also called "overtopped."

Susceptible—Likely to become damaged as a result of contact with an insect pest.

Terminal branch—The uppermost branch or leader on a tree, especially conifers.

Top-kill—Mortality of the top portion of the crown of a tree.

Uneven-age management—A silvicultural system designed to produce a stand in which three or more age classes are represented.

Vascular—Refers to the water-conducting tissue in plants and trees.

Wetwood—Wood that is altered by microorganisms so that discoloration, moisture, pH, and mineral content increase, and certain parts of the cell walls may be eroded.

Xylem—See **sapwood**.

Index

Alder 7, 13, 19, 25, 35, 36
  red *Alnus rubra* 9, 11

Ash *Fraxinus latifolia* 7, 19, 25, 35

Aspen *Populus tremuloides* 7, 8, 19, 25, 35

Birch *Betula papyrifera* 7, 9, 25, 35

Buckthorn *Rhamnus purshiana* 7, 19, 25, 35

Cedar 30, 36
  Alaska- *Chamaecyparis nootkatensis* 6, 18, 24, 34
  incense- *Calocedrus decurrens* 6, 18, 24, 30, 34
  Port-Orford- *Chamaecyparis lawsoniana* 6, 18, 24, 30, 34
  western red *Thuja plicata* 6, 18, 24, 34

Cherry *Prunus* spp. 7, 19, 25, 35

Chinkapin *Castanopsis* spp. 7, 19, 25, 35

Cottonwood *Populus trichocarpa* 7, 19, 25, 35

Dogwood *Cornus* spp. 7, 19, 25, 35

Douglas-fir *Pseudotsuga menziesii* 3, 5, 6, 8, 9, 10, 11, 13, 14, 15, 17, 18, 20, 21, 23, 24, 26, 28, 30, 31, 32, 33, 34, 36, 39

Fir (true) 5, 8, 9, 14, 15, 17, 20, 23, 26, 28, 31, 38, 39
  grand *Abies grandis* 6, 17, 18, 24, 28, 34, 37
  noble *Abies procera* 6, 17, 18, 24, 34
  Pacific silver *Abies amabilis* 6, 17, 18, 24, 34
  Shasta red *Abies magnifica* var. *shastensis* 6, 17, 18, 24, 28, 34, 38
  subalpine *Abies lasiocarpa* 6, 17, 18, 24, 34
  white *Abies concolor* 6, 8, 12, 18, 24, 28, 32, 34, 36, 38, 40

Hemlock 8, 11, 13, 23, 30, 36
  mountain *Tsuga mertensiana* 6, 18, 24, 34
  western *Tsuga heterophylla* 5, 6, 18, 24, 26, 34

Juniper *Juniperus* spp. 6, 13, 18, 24, 34

Larch 6, 12, 13, 18, 24, 34
  western *Larix occidentalis* 16, 28

Madrone *Arbutus* spp. 7, 19, 25, 35

Maple *Acer* spp. 7, 19, 25, 35

Myrtlewood *Umbellaria californica* 7, 19, 25, 35

Oak 7, 19, 25, 35
  Oregon white *Quercus garryana* 11, 20

Pine 5, 8, 10, 12, 13, 14, 26, 30, 31, 32
  Jeffrey *Pinus jeffreyi* 6, 10, 12, 13, 17, 18, 20, 24, 26, 34
  knobcone *Pinus attenuata* 6, 17, 18, 24, 34
  limber *Pinus flexilis* 6, 18, 24, 34
  lodgepole *Pinus contorta* var. *latifolia* 6, 10, 12, 13, 17, 18, 20, 23, 24, 26, 27
  ponderosa *Pinus ponderosa* 6, 9, 10, 12, 13, 17, 18, 20, 22, 23, 24, 26, 27, 29, 30, 33, 34, 36, 37, 38, 39
  shore *Pinus contorta* var. *contorta* 17, 23
  sugar *Pinus lambertiana* 6, 10, 12, 13, 18, 20, 23, 24, 26, 27, 30, 34
  western white *Pinus monticola* 3, 6, 13, 18, 24, 26, 27, 30, 34
  whitebark *Pinus albicaulis* 6, 18, 24, 26, 34

Redwood *Sequoia sempervirens* 6, 18, 24, 34

Spruce 5, 8, 14, 17, 22, 26, 29, 31, 36
  Brewer *Picea breweriana* 6, 18, 24, 34
  Engelmann *Picea engelmannii* 5, 6, 9, 12, 18, 21, 23, 24, 28, 29, 34
  Sitka *Picea sitchensis* 5, 6, 11, 18, 21, 22, 23, 24, 29, 34

Tanoak *Lithocarpus densiflorus* 7, 19, 25, 35

Willow *Salix* spp. 7, 13, 19, 23, 25, 35

Yew *Taxus brevifolia* 6, 18, 24, 26, 34

This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties.

Published November 1998.