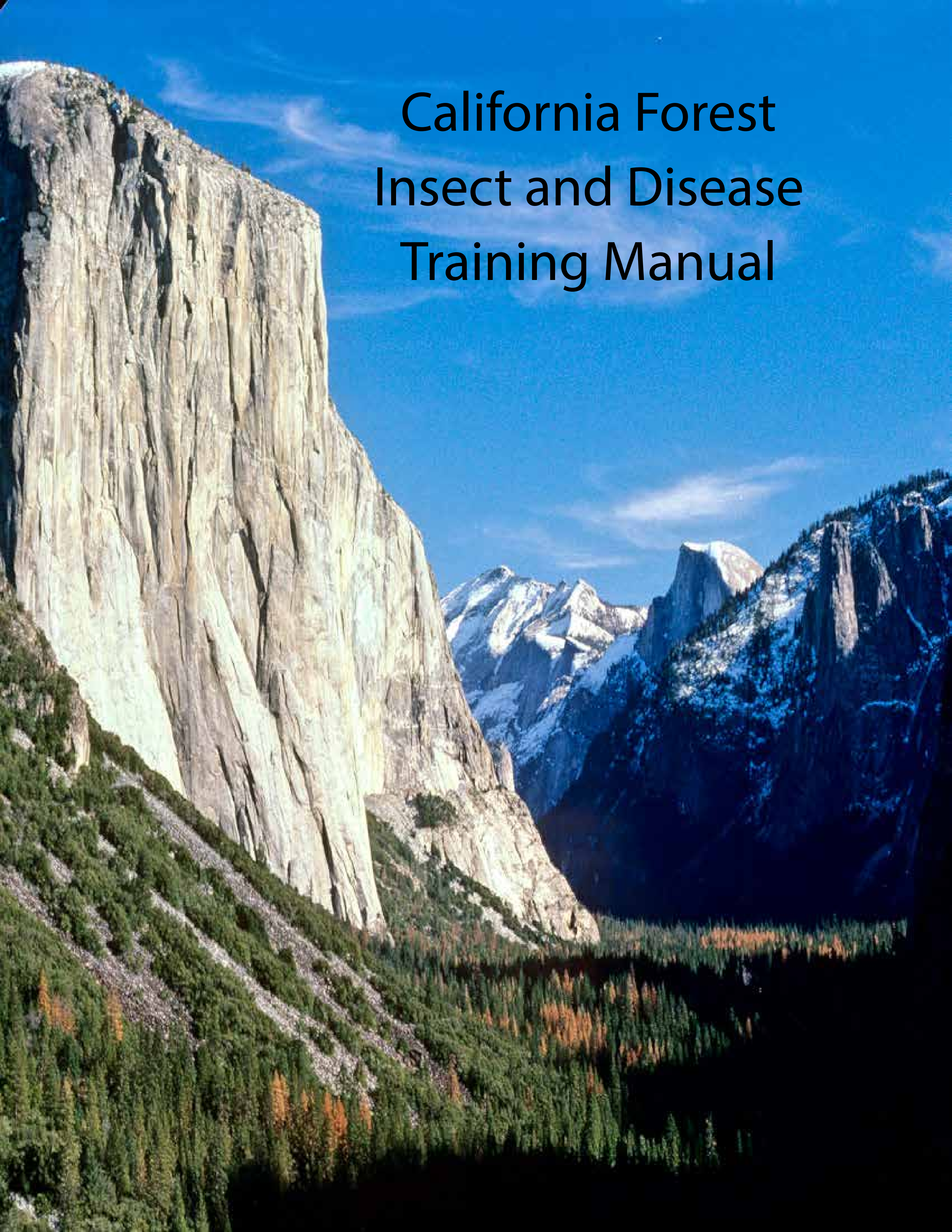
California Forest Insect and Disease Training Manual



This document was created by US Forest Service, Region 5, Forest Health Protection and the California Department of Forestry and Fire Protection, Forest Pest Management forest health specialists. The following publications and references were used for guidance and supplemental text:

Forest Insect and Disease Identification and Management (training manual). North Dakota Forest Service, US Forest Service, Region 1, Forest Health Protection, Montana Department of Natural Resources and Conservation and Idaho Department of Lands.

Forest Insects and Diseases, Natural Resources Institute. US Forest Service, Region 6, Forest Health Protection.

Forest Insect and Disease Leaflets. USDA Forest Service

Furniss, R.L., and Carolin, V.M. 1977. Western forest insects. USDA Forest Service Miscellaneous Publication 1339. 654 p.

Goheen, E.M. and E.A. Willhite. 2006. Field Guide to Common Disease and Insect Pests of Oregon and Washington Conifers. R6-NR-FID-PR-01-06. Portland, OR. USDA Forest Service, Pacific Northwest Region. 327 p.

M.L. Fairweather, McMillin, J., Rogers, T., Conklin, D. and B Fitzgibbon. 2006. Field Guide to Insects and Diseases of Arizona and New Mexico. USDA Forest Service. MB-R3-16-3.

Pest Alerts. USDA Forest Service.

Scharpf, R. F., tech coord. 1993. Diseases of Pacific Coast Conifers. USDA For. Serv. Ag. Hndbk. 521. 199 p.32, 58.

Tree Notes Series. California Department of Forestry and Fire Protection.

Wood, D.L., T.W. Koerber, R.F. Scharpf and A.J. Storer, Pests of the Native California Conifers, California Natural History Series, University of California Press, 2003.

Cover Photo: Don Owen. 1978. Yosemite Valley.

California Forest Health Specialists

US Forest Service, Forest Health Protection
http://www.fs.usda.gov/main/r5/forest-grasslandhealth

US Forest Service, Regional Office
1323 Club Drive, Vallejo, CA 94592; Phone: 5707-562-8921, FAX 707-562-9054
Sheri Smith, Regional Entomologist: ssmith@fs.fed.us; Phone: 530-252-6667
Phil Cannon, Regional Pathologist: pcannon@fs.fed.us; Phone 707-562-8913

Northeastern California Shared Service Area at the Lassen National Forest
2550 Riverside Drive, Susanville, CA 96130; Phone 530-257-2151, FAX 530-252-6428
Danny Cluck, Entomologist: dcluck@fs.fed.us; Phone 530-252-6431
Bill Woodruff, Pathologist: wwoodruff@fs.fed.us; Phone 530-252-6680

Northern California Shared Service Area at Shasta-Trinity National Forest
3644 Avtech Parkway, Redding, CA 96002; Phone 530-226-2436; FAX 530-226-2485
Cynthia Snyder, Entomologist: clsnyder@fs.fed.us; Phone 530-226-2437

South Sierra Shared Service Area at Stanislaus National Forest
19777 Greenley Road, Sonora, CA 95370; Phone 209-532-3671, FAX: 209-533-1890
Beverly Bulaon, Entomologist: bbulaon@fs.fed.us; Phone 209-532-3672 ext.323
Martin MacKenzie, Pathologist: mmackenzie@fs.fed.us; Phone 209-532-3672 ext. 242

Southern California Shared Service Area at San Bernardino National Forest
602 S. Tippecanoe Avenue, San Bernardino, CA 92406; Phone 909-382-2600, FAX 909-383-5770
Andrea Hefty, Entomologist: ahefty@fs.fed.us; Phone 909-382-2871
Stacy Hishinuma, Entomologist: shishinuma@fs.fed.us; Phone 909-382-2620

State & Private Forestry, Forest Health Monitoring and Aviation Management
1731 Research Park Drive, Davis, CA 95616; Phone 530-759-1748, FAX 530-756-4324
Jeff Moore, Aerial Survey Program Manager; jwmoore02@fs.fed.us; Phone 530-759-1753
Jackie Pope, Natural Resource Specialist; jacquelinehpope@fs.fed.us; Phone 530-759-1751

State of California, Department of Forestry and Fire Protection, Forest Pest Management, *http://www.fire.ca.gov*

CALFIRE State Headquarters
1416 Ninth Street, PO Box 944246, Sacramento 94244; Phone 916-653-5123

Forest Pest Management, CA Dept. of Forestry and Fire Protection
2690 North State Street, Ukiah, CA 95482; Phone 707-462-5886
Chris Lee, Forest Health Specialist: christopher.lee@fire.ca.gov

Forest Pest Management, CA Dept. of Forestry and Fire Protection
P.O. Box 944246, Sacramento, CA 94244; Phone 916-653-9476
Tom Smith, Forest Health Specialist: tom.smith@fire.ca.gov

Forest Pest Management, CA Dept. of Forestry and Fire Protection
6105 Airport Road, Redding, CA 96002; Phone 916-201-7032
Curtis Ewing, Forest Health Specialist: curtis.ewing@fire.ca.gov

Forest Pest Management, CA Dept. of Forestry and Fire Protection
880 Los Osos CA 95402; Phone 805-550-8583
Kim Corella, (previously Camilli), Forest Health Specialist: kim.camilli@fire.ca.gov

Table of Contents

Appendices

Tables

Figures

What is a Pest?

A pest can be defined as a plant, animal, insect, or pathogen, acting singly or in combination, often aggravated by environmental stressors, which by its presence, abundance, or activity interferes with accomplishment of resource management goals and objectives. Native insects and diseases are established elements of forest and range ecosystems, along with other animals and plants, and are not considered pests *a priori*.

Even when management goals and objectives are clearly defined, it is often difficult to determine, especially quantitatively, when and under what circumstances an organism, or complex of organisms, is a pest. It is therefore useful to distinguish between injury, damage, loss, and impact.

Injury is an abnormality in form or function in a given host caused by a foreign agent (a canker, defoliation, larval galleries, galls, etc.). Injury does not necessarily imply damage. Damage is any adverse effect(s) on a particular forest resource caused, or contributed to, by an organism, groups of organisms, or environmental stress and includes mortality, growth loss, and deformation. Loss is a quantitative measurement of damage – the difference in resource outputs attributable to the damage as compared to the same resource outputs in the absence of the damage. Impact is the net effect(s) of a given organism, group of organisms, and/or environmental stresses on the productivity, usefulness, and values of a given resource with respect to specific resource management goals and objectives. *An insect or disease becomes a pest only when it causes, or contributes to, unacceptable negative impacts on defined management goals and objectives*. The presence of injury or damage symptoms is not synonymous with negative impact.

Pest – Ecosystem Interactions

Forest pests do not operate outside of or separately from the forest ecosystem, but rather are an interactive part of this system. As such, they affect and are affected by the forest ecosystem both directly and indirectly.

A pest situation can exist only when the proper conditions are met at each of the three corners of the pest triangle. Removing or changing the agent or host, or changing the environment, may eliminate the undesirable pest situation.

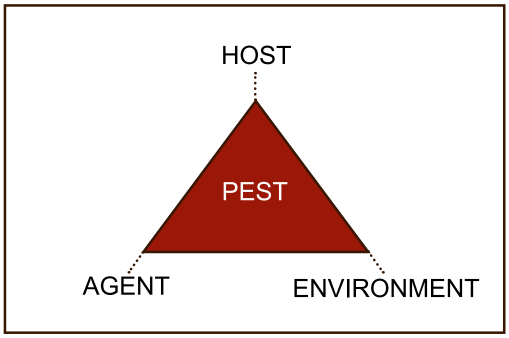


Figure 1. A triangle can be used to illustrate the interactions between the pest, host, and environment.

By recognizing the importance and role of each corner of the pest triangle, we should have a better understanding of the pest situation and its effects, and anticipate its future course. With these ideas, a great many more opportunities for controlling the problem are available. Control in the broad sense includes any direct or indirect efforts to prevent or reduce losses; the objective of control is to reduce pest losses, not to kill pests. Efforts to control a pest problem can be aimed at any corner of the pest triangle. By bringing about the right change in any one of these three factors we can reduce pest-caused losses. For example, we can bring about changes in the host by increasing host vigor or changing the species mix or age class to one that is more resistant to the pest. We can destroy members of an agent's population or obstruct the completion of some portion of the agent's life cycle.

Methods by which we can reduce pest impact by changing the immediate environment are not as readily obvious. Factors which are included in the environmental corner of the triangle include both biological and physical factors.

An example of a biological environmental factor is another organism which affects the pest situation. One agent may affect a host in such a manner so as to predispose it to other pest agents. These situations are often common and predictable and we refer to these as "pest complexes." Two common pest complexes encountered in California are dwarf mistletoe/bark beetle complexes and root disease/bark beetle complexes. In both of these complexes, the parasite or pathogen involved (dwarf mistletoe or the root disease fungus) reduces the trees' vigor and natural defenses, predisposing them to successful bark beetle attack, which kills the trees. Thus, we can reduce the impact of the beetles by aiming our control measures at the dwarf mistletoe or root disease.

Examples of physical factors included in the environmental corner of the pest triangle are stand and site conditions. These conditions affect host vigor, which in turn affects the success of a pest attack. In the event of pest complexes, the stand and site conditions may affect either pest thus minimizing or aggravating the damage. This effect is often most noticeable where unfavorable stand or site conditions aggravate the effects of the predisposing pest, resulting in increased damage and mortality by the consequent pest. Thus, we can manipulate stand conditions to favor host resistance or decrease the initial pest's ability to cause damage.

What is Integrated Pest Management?

The consideration of all aspects of the pest triangle when dealing with pest situations and their control exemplifies an approach to pest management known as integrated pest management (IPM). Integrated pest management is a concept, or an approach, not a specific technique or control action. IPM is a decision support system for resource management incorporating pest management considerations with the forest and rangeland resource management assessment, evaluation, planning, and decision-making process.

The following definitions serve to illustrate what IPM is and how it is perceived by Forest Health Specialists in California:

1. "Integrated Pest Management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates that they are needed according to established guidelines, and treatments are made with the goal of removing only the target organisms. Pest control materials are selected and applied in a manner that minimizes risks to human health, to beneficial and nontarget organisms, and to the environment." (IPM in Practice – Principles and Methods of Integrated Pest Management" UC ANR Pub. No. 3418 (2001))

2. "Integrated Pest Management (IPM). A pest control strategy based on the determination of an economic, human health, or environmental threshold that indicates when a pest population is approaching the level at which control measures are necessary to prevent the decline in the desired conditions. In principle, IPM is an ecologically based holistic strategy that relies on natural mortality factors, such as natural enemies, weather, and environmental management, and seeks control tactics that disrupt these factors as little as possible. It is the planned and systematic use of detection, evaluation, and monitoring techniques, and all appropriate silvicultural, biological, chemical, genetic, and mechanical tactics needed to prevent or reduce pest-caused damage and losses to levels that are economically, environmentally, and aesthetically acceptable. (FSM 2150 manual)

3. IPM is "a process wherein pest management considerations are integrated with resource management considerations to achieve targeted goals and objectives." (Douglas R. Liesz, Regional Forester, Pacific Southwest Region, 1976)

4. IPM is "the maintenance of destructive agents, including insects at tolerable levels by the planned use of a variety of preventive, suppressive, or regulatory tactics or strategies that are ecologically and economically efficient and socially acceptable. It is implicit that the actions taken are fully integrated into the total resource management

process in both planning and operation. (Handbook, California Dept. of Forestry and Fire Protection, Section 5080.1, Forest Pest Policy)"

The IPM Approach in Forest Pest Management

The objective of Forest Health Protection (FHP) is to reduce damage, loss, and impacts caused by pests (insects, diseases, vegetation, and animals) on all forests and rangelands to levels commensurate with resource management objectives.

It is the responsibility (FSM 3404.21) of FHP to:

1. Provide advice and guidance to national Forests, other Federal agencies, and States on forest pest management and pesticide use;
2. Conduct surveillance and detection surveys to ensure prompt discovery of potentially threatening pest populations and/or damage to forest vegetation;
3. Conduct biological evaluations to determine the need to initiate, continue, intensify, revise, or discontinue pest management activities and, upon request, make pest management recommendations;
4. Work with Federal and State personnel to evaluate and determine the need to initiate, continue, intensify, revise, or discontinue pest management activities and, upon request, make pest management recommendations;
5. Conduct pest management training for resource managers, and provide specialized training for Forest and District unit pest management specialists to facilitate the training and certification of pesticide applicators;
6. Identify forest pest problems as candidates for research programs; and
7. Transfer technology through field studies, pilot projects, demonstration areas, and technical assistance.

In carrying out these responsibilities, Forest Health Protection uses the integrated pest management approach to maximize pest management effectiveness and efficiency while minimizing adverse impacts to humans and their environment.

Implementation of Integrated Pest Management

The actual implementation of the IPM approach involves a series of formal steps or elements, which are separate, but ideally function as part of a continuum. These steps are 1) prevention, 2) detection, 3) evaluation, 4) suppression, and 5) monitoring.

Prevention

Taking steps to avoid completely, or to reduce the impact of, a pest-related problem before it occurs is a key element of the IPM approach. There are several general categories of prevention. These include:

- Regulatory measures – quarantine
- Cultural measures
- Matching site and planting stock
- Regulating stand density, compositions, and age
- Eradicating alternate hosts
- Avoiding site and tree injury
- Timing activities

- Reducing numbers of breeding habitats
- Using chemicals
- Using biological control agents
- Use of genetically resistant stock

Detection

The early discovery of potential pest problems is critical to successfully preventing pest-caused damage. Detection is the discovery, identification, and reporting of damaging insects, diseases, animals, introduced plants, and environmental stresses.

Detection has two phases: ***Surveillance*** is carried out by persons working in the forest on a day-to-day basis in connection with their regular duties. Surveillance is an ongoing, continuous effort. Surveillance can at times be supplemented by ***detection surveys,*** which are planned, organized, and conducted for specific purposes or objectives.

Evaluation

The evaluation process includes gathering, analyzing, and interpreting technical data to provide a sound base for predicting damage and selecting the alternative(s) best suited to meet management goals and objectives (decision-making). Evaluations consider the biological, environmental, and economic feasibility of possible pest management strategies. Biological evaluations appraise the current and potential significance of a pest problem. There are typically three phases to this evaluation: 1) diagnosis, 2) prognosis, and 3) identification and discussion of alternatives. The biological evaluation should provide the resource manager with enough information to make an initial decision as to what, if anything should be done about the problem.

Types of biological evaluations include risk, initial, pre-treatment, and post-treatment evaluations. A risk evaluation predicts the susceptibility of stands to pest attack. An initial evaluation provides the resource manager who has a potential pest problem with the biological information necessary to make a decision on whether control action is needed. A pre-treatment evaluation verifies that treatment is still needed, and a post-treatment evaluation compares the actual effects of a treatment with the predicted effects.

Suppression

Suppression refers to the reduction of pest-related damage to acceptable levels through the application, individually or in some optimal combination, of various techniques, including silvicultural, mechanical, chemical, or biological methods. The intent or purpose of suppression is ***not*** to kill pests, but to prevent or reduce unacceptable loss so that management goals and objectives can be achieved.

Monitoring

Typically, monitoring is narrowly interpreted as the post-treatment evaluation – that is, an assessment to determine how well the prevention and suppression treatment method(s) used met the intended objectives. In the broad context of IPM, however, it has become more appropriate to evaluate the entire process, not just the prevention and suppression elements, in order to improve implementation of the process.

Steps of Diagnosis

Accurate diagnosis of tree health problems is necessary for successful achievement of land management objectives. Many problems can be minimized or altogether prevented by the knowledgeable manipulation of species composition, stand density, and stand structure using common silvicultural practices such as planting and thinning. Forest managers require an awareness and basic understanding of common tree health problems existing in their geographic area so they can effectively integrate preventative practices into their forest management plans. Tree health problems, most commonly perceived at the stand level, sometimes may be indicative of underlying, larger-scale forest health problems.

Causes Of Tree Injury

A multitude of organisms and abiotic factors may cause tree injury and mortality. Many of these are included in the table below.

Table 1. Causes of Injury to Living Trees in California

Causes of injury to living trees in California					
Biotic			Abiotic		
Insects	**Pathogens**	**Wildlife**	**Human-Origin**	**Weather**	**Other**
Bark beetles and wood borers	Root disease fungi	Bears	Herbicides	Drought	Fire
Defoliators	Dwarf mistletoes	Ungulates	Air pollution	Wind	Poor soil
Terminal and shoot feeders	Canker-causing fungi	Rodents	Covering roots with displaced soil, pavement	Frost	Nutrient imbalances
Root feeders	Stem decay fungi	Sapsuckers	Soil compaction	Flooding	Landslides
Sucking insects and mites	Other brooming agents		Poor planting technique	Winter desiccation	Avalanches
Introduced (exotic) insects	Foliar pathogens		Offsite seed source planting	High temperature	
	Introduced (exotic) pathogens			Lightning	
				Snow, ice	

Primary Agents vs. Secondary Agents

Insect and disease agents are sometimes classified into two categories, primary and secondary, depending on their ability to cause tree mortality in the absence of other predisposing factors. Primary agents frequently kill the trees they affect, acting alone or in concert with other agents or factors. Secondary agents may cause tree injury or predispose trees to attack by other agents, but seldom cause tree mortality under natural forest conditions.

Complexes Are Common

Frequently, more than one causal factor contributes to tree mortality, and certain sets of factors are commonly found in association with one another. For example, abiotic factors frequently function as stressors, predisposing trees to mortality caused by biotic agents. Some other common associations include root diseases/bark beetles, bark beetles/wood borers, canker-causing rust fungi/rodents, dwarf mistletoes/stem decay fungi, and offsite seed source plantings/foliar pathogens.

What's Wrong With My Trees?

Deviation from the usual appearance of a thriving, healthy tree frequently develops in response to damaging agents. Changes occur in the physical characteristics of the tree in terms of crown coloration, foliage retention, foliage size or shape, crown form, atypical swellings or resin flows on the stem or branches, an unusually heavy cone crop, or dead portions of the crown that cannot be attributed to natural pruning. Generally speaking, each type of damage agent tends to be associated with a unique array and presentation of the above symptoms. Due to this fact, symptoms offer important clues for aiding diagnosis of the causal agent, though they sometimes fail to offer information that is specific enough to allow final diagnosis, e.g. missing needles.

Searching For Clues

Accurate diagnosis of tree health problems may be compared to solving a mystery. Clues must be gathered, and then a series of deductive steps followed to arrive at the proper conclusion. Generally speaking, the greater number of clues used to diagnose a problem, the higher the likelihood of arriving at a correct diagnosis. This is because a complex of factors usually affects trees, and sometimes what appears to be the most obvious culprit is actually a secondary occurrence to the "real" problem. A good example of this is when bark beetles kill trees infected with root disease. Although the bark beetles may be the most obvious agent associated with tree mortality, the "real" problem is the more cryptic root disease.

Look For Symptoms, Signs, and Context

So what clues does one look for? In addition to tree symptoms, probably some of the most helpful clues are those produced by the damaging agents themselves. These clues, commonly called "signs", include the presence of the physical body or body parts of the causal agent, such as insect larvae, conks, or mistletoe plants, or evidence that is directly related to it, such as chewed needles, insect frass, bark beetle galleries, wood decay characteristics, or sapsucker holes. Signs are not always evident, due to seasonal development cycles, transience, or a cryptic nature.

Other important clues may be gathered by considering the "context" of the injury, represented by geographic location (e.g. western coastal lowlands), topographic location (elevation, aspect, floodplain, ridgetop, etc.), site history (e.g. drought, windthrow events, management activities, offsite seed source, etc.), setting (e.g. natural, intensively managed, urban), and forest characteristics (e.g. pure or mixed species, structural stage such as plantation or old growth, stand density, etc.).

Look For Patterns

Although the inherent physical characteristics (form, color and shape) of signs and symptoms themselves are often key distinguishing features, their patterns of distribution across space and time also provide critical information. Observations of patterns should be made both on the level of the individual tree as well as the surrounding stand. What portion of the tree is affected? How is the injury distributed on and among trees? Which species are affected? Which ages or sizes? Is the injury scattered or grouped? Does the injury appear to be chronic, a single event, or successive single events? What time of year did the injury occur? Considered together, signs and symptoms and their distribution and development patterns provide a reliable basis for establishing the identity of most damaging agents.

Because most biotic agents are quite host-specific and usually restricted to a relatively small number of primary host tree species, and because they are usually specialized to exploit a specific portion of the tree, biotic agents tend to produce non-uniform but consistent patterns of injury both within a tree and across a stand. Injury caused by biotic agents is usually limited in terms of tree species, age, size, part of tree, or age of foliage, and typically occurs in irregularly scattered or clumped distributions. Conversely, abiotic agents tend to produce injury patterns that are more uniform across an area and non-specific, and which are more closely associated with terrain, aspect, elevation, height above the ground, or physical proximity to human-associated disturbance or development than with tree attributes such as species, size, or age of foliage.

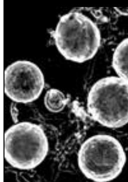
Diagnosis Steps

Become familiar with the signs, symptoms, and development patterns of major damaging agents in your area. When diagnosing problems, inspect symptomatic, dying, and dead trees, standing and fallen. Remember to look for patterns at the tree AND stand levels, and on temporal as well as spatial scales. Be aware of common associations and relationships among damaging agents. Diagnosis of tree health problems is not a linear process; rather it involves the inclusion of several steps that are somewhat interchangeable. Following is one approach:

1. Observe the injury.
2. Note symptoms and their pattern of distribution in the affected trees, e.g. affected species, tree part, etc.
3. Examine symptomatic, dying, and dead trees for signs of the causal agent. Stumps, the exposed roots of down trees, and standing dead trees are particularly valuable resources for detecting signs of root disease. Look on foliage and branches, on and under the bark of stems and roots; look at wood decay characteristics of intermixed stumps, snags, and windthrows; inspect the ground under affected trees for soil compaction, conks, or fallen branches containing signs.
4. Examine affected area for patterns of injury distribution and symptom development over time.
5. Note context of the injury, i.e. site history, location, setting, and forest characteristics.
6. After assembling as many clues as possible, identify potential causal factors.
7. Evaluate the relative importance of potential causal factors to tree health problems based on knowledge of primary vs. secondary agents, common associations among damaging agents, and known relationships of site, stand, and damaging agents in that area.
8. Arrive at diagnosis.

Resources

Handy fingertip assistance in diagnosis in the form of reference books and field guides on tree pest and damage identification is available at libraries, bookstores, and through government offices. Many excellent websites also provide useful information and photos of tree damage and causal agents. Several references and web site links are provided in the final sections of this training manual (see page 235). In addition, pathologists, entomologists, and other specialists in tree damage assessment may be consulted at many state and federal natural resource agencies, and at local county extension offices.



Forest Tree Diseases

What is a Disease?

Disease may be defined as an abnormal and injurious physiological activity due to continual irritation of a primary causal agent, manifested in symptoms. A tree disease usually involves a complex relationship among 1) the host tree, 2) a conducive environment, and 3) a biotic, infective causal agent called a pathogen.

Agents that incite disease may be abiotic or biotic. Abiotic causal agents are those that are non-infectious, such as nutrient deficiencies or excesses and air pollution. Biotic causal agents are those which are infectious, such as viruses, bacteria, and fungi. The most important biotic causal agents of disease in California trees are fungi and parasitic higher plants.

Fungi are filamentous organisms that lack chlorophyll, and therefore must obtain nutrients from host plants or other nutrient-rich substrates. They spread via wind or water-borne spores that are released from fruiting bodies (conks, mushrooms, microscopic fruiting structures), by growing short distances through the soil, or by growing across plant contacts.

Parasitic higher plants depend on living hosts for survival. They rely on their hosts for water and sometimes, nutrients. Depending on the taxa, they contain varying levels of chlorophyll, which allows them to produce at least some of their food. They reproduce by seeds. Seeds may be moved by animals, particularly small mammals and birds, or they may have specialized mechanisms that facilitate short-distance spread on their own.

A disease is usually characterized by a particular set of symptoms and signs. The act of identifying diseases based on symptoms and signs is called diagnosis. Additional information on identifying insect and disease problems is given in the “Steps Of Diagnosis” chapter of this manual.

Symptoms are the detectable host reactions to a pathogen. These include such things as needle loss, foliage color change, decreased growth, resin production and decayed wood. Symptoms may be either localized in a particular part of the tree, or systemic (generalized throughout the tree). In addition, symptoms may be primary (direct and immediate changes in tissues infected by a pathogen or caused by other disease agents) or secondary (indirect and subsequent physiological effects on tissue induced by action at a point distant from the actual infection or action). The sequence of symptom development is frequently characteristic of a particular disease.

Signs are observable structures of the agent that causes the disease. The most common signs are reproductive or vegetative parts of a pathogen or parasite, such as the fruiting bodies, spores, and vegetative mycelium of fungi and the basal cups of dwarf mistletoe. Signs are usually of greater diagnostic value than are symptoms because: (1) different causal agents may incite similar symptoms, (2) our ability to distinguish between similar symptoms is limited, and (3) we are accustomed to think of a disease in terms of its immediate causal agent.

Insect/Disease Interactions

Phytophagous (plant eating) insects and tree pathogens are often close associates in forests, and, usually, a forest will be influenced by a number of different diseases and insects concurrently. Sometimes this is coincidental and sometimes it results from occurrence of high concentrations of particular host trees that are highly susceptible to a number of different insects and diseases, but often it is the result of complex interactions among insects and disease organisms. One organism may affect a tree and weaken it, predisposing it to attack by another, or one organism may actually introduce another organism into the host. A forest manager who is considering insects and diseases in a prescription needs to identify *all* important insects and diseases and not just the single most obvious one in any given case. Careful, complete diagnosis is important.

Roles of Pathogens in Forest Ecosystems

Tree pathogens act as agents of diversity in natural forest ecosystems. They influence forest composition, structure, and density by selectively killing or slowing the growth of some tree species while affecting others to a lesser degree or not at all. They may preferentially affect some tree species over others or they may impact low vigor trees more than vigorous ones of the same species. Their impacts may be highly correlated with tree age or stage of stand development. They have important roles in creating small canopy gaps and specialized wildlife habitat, and they are significantly involved in nutrient recycling.

Through the millions of years that pathogens have existed with host plants in natural ecosystems, they have coevolved to a reasonable balance that permits populations of each to survive. There are, however, two situations where the balances observed in natural ecosystems break down: 1) when non-native pathogens are introduced into an area, and 2) when ecosystems change rapidly from their "natural" conditions. Examples of the first include the devastating effects of the introductions of white pine blister rust, sudden oak death, Port-Orford-cedar root disease, Dutch elm disease, chestnut blight and a long list of other exotic diseases in the forests of the world. Examples of the second involve the serious impacts of native diseases by such things as fire exclusion, inappropriate harvesting, planting of off-site stock, climate change, and excessive soil compaction. Unfortunately, these situations are all too common in the forests of California.

*See the following page for Summary of Host/Disease Relationships in California

Summary of selected Host/Pathogen Relationships in California
(see reverse side for host and mistletoe keys)

DISEASE TYPE	PP	JP	SP	WWP	LP	CP	PiP	GP	MP	KP	DF	WF	RF	BS	IC	GS	WJ	POC	BO	LO
ROOT DISEASE:																				
Heterobasidion:																				
H. irregulare	X	X	X	X	X	X		X	X	X					X		X			
H. occidentale											X	X	X			X				
Black Stain:																				
Pine Variant	X	X	X		X															
DF Variant											X									
Pinyon Variant							X													
Armillaria	X	X	X	X	X				X	X	X	X	X		X	X	X	X	X	X
Port-Orford-Cedar																		X		
DWARF MISTLETOE:	*Acamp*	*Acamp*	*Acali*	*Amont, Occ. Acyan*	*Aamer*	*Acamp*	*Adiva*	*Aocci*	*Alitt*	*Asisk, Occ. Acamp*	*Adoug*	*Aconc Occ. Awien*	*Amagn Occ. Awien*	*Awien*						
LEAFY MISTLETOE:												*Ppauc*			*Plibo*		*Pjuni*		*Pvill*	*Pvill*
RUSTS:																				
Western gall	X	X			X	X		X	X	X										
WP Blister			X	X																
Filamentosum	X	X		X	X	X														
Yellow witch's broom												X	X							
Incense cedar rust															X					
CANKER/NEEDLE DISEASE:																				
Elytroderma	X	X			X	X	X			X										
Diplodia (Sphaeropsis)	X								X											
Dermea											X									
Phomopsis											X									
Atropellis	X		X	X	X															
DECAYS:																				
Red ring rot	X	X	X	X	X	X	X		X	X	X			X				X		
Indian paint												X	X							
Pecky rot															X					
Red brown butt rot	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Brown trunk rot	X	X	X	X	X						X									
Sulfur fungus	X	X	X	X	X	X					X	X	X	X		X	X		X	X
PITCH CANKER:									X	X										

Table 2. Summary of Selected Host/Pathogen Relationships in California (see reverse side for host and mistletoe keys)

HOST KEY:

PP = ponderosa pine
JP = Jeffrey pine
SP = sugar pine
WWP = western white pine
LP = lodgepole pine
CP = Coulter pine
PiP = pinyon pine
GP = gray pine
MP = Monterey pine
KP = knobcone pine
BS = Brewer Spruce
DF = Douglas-fir
WF = white fir
RF = red fir
IC = incense cedar
GS = giant sequoia
WJ = western juniper
POC = Port Orford cedar
BO = California black oak
LO = live oak

MISTLETOE KEY:

Aamer = *A. americanum* , lodgepole pine dwarf mistletoe
Acali = *A. californicum* , sugar pine dwarf mistletoe
Acamp = *A. campylopodum* , western dwarf mistletoe
Aconc = *A. abietinum f* sp. *concoloris* , white fir dwarf mistletoe
Acyan = *A. cyanocarpum*, limber pine dwarf mistletoe
Adiva = *A. divaricatum* , pinyon pine dwarf mistletoe
Adoug = *A. douglasii* , Douglas-fir dwarf mistletoe
Alitt = *A. littorum* , coastal dwarf mistletoe
Amagn = *A. abietinum f* sp. *magnificae* , red fir dwarf mistletoe
Amont = *A. monticola* , western white pine dwarf mistletoe
Aocci = *A. occidentale*, gray pine dwarf mistletoe
Asisk = *A. siskiyouense* , knobcone pine dwarf mistletoe
Awien = *A. abietinum* spp. *wiensii*, Wiens' dwarf mistletoe

Pboll = *Phoradendron pauciflorum* , white fir mistletoe
Pjuni = *P. juniperinum*, juniper mistletoe
Plibo = *P. libocedri* , incense cedar mistletoe
Pvill = *P. villosum*, oak mistletoe

Mistletoes

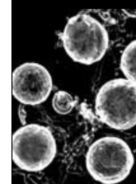
The parasitic flowering plants commonly known as mistletoes are found throughout North America. Two genera of mistletoes are native to California: Phoradendron (true mistletoes) and Arceuthobium (dwarf mistletoes). The non-native European mistletoe (Viscum album) was introduced into Sonoma County in about 1900, and continues to spread in several hardwood species in a localized infestation around Sebastopol.

The true mistletoes grow on both conifers and broadleaf trees; the dwarf mistletoes grow only on conifers. Male and female flowers are produced on separate plants in both genera.

Many true mistletoes produce woody mature shoots more than 2 feet (0.6 m) long and 2 inches (5 cm) or more in diameter. All true mistletoes produce mature plants larger than 6 inches in length. Foliage is usually green and leafy; however some species are yellow-to-green and have their leaves reduced to small scales. The fruit are white or pink berries. On the Pacific Coast, the four true mistletoes on conifers are easily distinguished on the basis of foliage characteristics and the host species.

In contrast, dwarf mistletoes are small plants, with mature shoots less than 6 to 8 inches (15 to 20 cm) long and 2 to 5 mm in diameter. The shoots are non-woody, segmented, and have scale-like leaves. Seeds produced in oval-shaped bicolor fruit are forcibly released when ripe.

Although both mistletoes are damaging parasites of trees, by far the greatest timber loss in coniferous forests of the western United States is attributed to the dwarf mistletoes. Billions of board feet of lumber are lost each year as a result of growth reduction and mortality from these parasites. They also cause serious damage to high-value, high-use forest recreation areas.



True Mistletoes (*Phoradendron* spp.)

Hosts: Fraxinus, Populus, Quercus, Salix, Alnus Platanus, Acer, Juglans, Abies, Libocedrus, Juniperus, Cupressus (see Table on page 15)

Distribution in California: Statewide

Characteristics: True (or leafy) mistletoes are found on both hardwoods and some conifers. They are woody plants with mature shoots usually more than six inches long. Their foliage may be leafy or scaly. Their fruit is a round berry with seeds, which are disseminated by birds. The leafy mistletoe found on hardwoods is often used for Christmas decorations. True mistletoe is important for wildlife forage, bird nesting, and the creation of cavities for wildlife use.

Disease Cycle: True mistletoe requires a living host, but manufactures its own food through photosynthesis. Because of this, it is only dependent on the host for water and mineral nutrients. True mistletoe is spread mainly by birds, including robins, bluebirds, thrushes, and cedar waxwings, that feed on the berries. Birds digest the pulp of the berries and expell the seeds, often depositing them onto susceptible trees. A viscous coating and hair-like threads on the outer surface of the seeds attach them firmly to twigs and branches, where they germinate and infect the host tissues with root-like structures that penetrate and grow inside the branches. Aerial shoots may not be produced for up to two years after infection.

Black oak infected with true mistletoe

Photo: C. Bryson

Young or small trees are seldom infected by leafy mistletoe. In nearly all cases, initial infection occurs on larger or older trees because birds prefer to perch in their tops. Severe buildup of mistletoe often occurs in an already infected tree because birds are attracted to and may spend prolonged periods feeding on the mistletoe berries.

Oak infected with true mistletoe

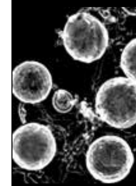
Photo: C. Bryson

Damage and Importance: The true mistletoes are usually considered to be curiosities and not as damaging as dwarf mistletoes, but they can be serious pests where individual trees are of high value, as in yards, parks, and campgrounds. Trees heavily infected by true mistletoe grow slowly and are weakened or sometimes killed, although it can take decades for mistloetoe to kill a mature tree. Weakened trees are predisposed to attacks by insects and often succumb during drought or other periods of stress. Branches and tree tops heavily laden with true mistletoe often break during storms or high winds, and trunk swellings may provide an entrance point for decay fungi, increasing the hazard to people and property in campgrounds and other developed sites.

Management Strategies: Control of true mistletoe is seldom practiced or needed in forest situations, other than selection against infected trees when practical. When control is desired for high-value ornamental trees, the mistletoe infection can either be pruned from the tree or aerial shoots can be removed. To prune branches of the tree, cut infected limbs 1 foot or more below the point of mistletoe attachment, preferably at the bole or a crotch. Drastic pruning that removes large amounts of tree foliage can be more damaging to the tree than the mistletoe itself. Consider treating all trees in an area, as pruned trees will most likely be reinfected by birds spreading seeds from nearby infected trees. Removing new mistletoe shoots each year will slow its development, but will not kill the parasite as the mistletoe can survive within the branch for many years and later develop new shoots on the surface from its root system within the tree branches. To kill the mistletoe plants, cut off the shoots flush with the limb or bole. Wrap the affected area with a band of black polyethylene to exclude light and and tie in place. Since the mistletoe will not survive without light, it may die within a year or two. If the area is not wrapped with plastic, new shoots will develop. Reinspect trees every 3-5 years after treatment. Consider planting non-host trees in the understory of infected trees.

Table 3. Species of *Phoradendron* in California

Species of *Phoradendron* in California		
Species	Common Name	Primary Hosts
On Hardwoods		
P. villosum	Oak Mistletoe	Oaks
P. macrophyllum	Big Leaf Mistletoe	Many hardwood species; especially poplar, ash, willow, sycamore
On Conifers		
P. libocedri	Incense-cedar Mistletoe	Incense-cedar
P. juniperinum	Juniper Mistletoe	Juniper
P. densum	Cypress-juniper Mistletoe	Cypress, Juniper
P. pauciflorum	Fir Mistletoe	White fir



References

Geils, B. W.; Cibrián Tovar, J.; and Moody, B., tech coords. 2002. Mistletoes of North American Conifers. Gen. Tech. Rep. RMRS – GTR-98. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 123 p.

Hawksworth. F.G. and Sharpf, R.F. 1981. *Phoradendron* on Conifers. U.S. Department of Agriculture, Forest Service, Forest Insect and Disease Leaflet No. 164, 7 p.

Mallams, K. M. and Mathiasen, R.L. 2010. Mistletoes on Hardwoods in the United States. U.S. Department of Agriculture, Forest Service, Forest Insect and Disease Leaflet No. 147, 12 p.

Mathiasen, R.L. Nickrent, D.L., Shaw, D.L. and Watson D.M. 2008. Mistletoes: Pathology, Systematics Ecology, and Management. Plant Disease 92(7): 988-1006.

Wiens, D. 1964. Revision of the acataphyllous species of *Phoradendron*. Brittonia 16: 11-54.

Wiens, D and Hawksworth, F. 2002. New species of *Phoradendron* (Viscaceae) from Mexico and Guatemala and a synopsis of species in section *Pauciflorae*. Aliso 21(1): 33–43.

Dwarf Mistletoes (*Arceuthobium spp.*)

Distribution in California: Statewide

Hosts: *Pinus. Pseudotsuga, Abies, Picea, Tsuga* (see Table on page 22)

Characteristics: Dwarf mistletoes have jointed shoots, which are less than six inches long. True leaves are lacking. The fruit is oval-shaped, containing one seed per fruit. The seed is forcibly discharged.

Dwarf mistletoes are obligate parasites; they are dependent on their hosts for water, minerals, and other nutrients. Once an infected tree or branch is cut the dwarf mistletoe cannot survive and is therefore not a threat. Dwarf mistletoes are host specific, usually confined to one host or a group of closely related species. It takes many years for populations to build up, and spread of the parasite in even-aged stands is only one to two feet per year. Young trees less than three feet in height are usually not infected from an associated infected overstory.

Symptoms and Signs: Dwarf mistletoe can be recognized in the field by:

- aerial shoots of the plant,
- swelling of infected branches or stems,
- presence of witches' brooms (dense masses of distorted branches),
- associated branch flagging caused by subsequent infection by the canker-causing fungus *Cytospora abietis* (in true firs).

Disease Cycle: The life cycle of a dwarf mistletoe begins with the dispersal of its small, greenish seeds. Mistletoe seeds are produced in small berries on female plants. Dispersal usually occurs in late summer or early fall. Seeds are disseminated by a hydrostatically controlled explosive mechanism. The seed is shot through the air as a result of water pressure buildup inside the berry as it ripens. When a seed lands on a susceptible host needle, it will colonize it if conditions are favorable. Maximum dispersal distance is about 16 m (48 ft), but dispersal distances of 10 m (30 ft) or less are more typical. A seed that lands on a needle of a host tree remains there because it is coated with a sticky substance called "viscin" that readily adheres to any object it strikes. Intercepted seeds usually remain on the needles until the first rain wets the viscin. The viscin is hygroscopic so it becomes slippery when moistened. Gravity pulls the well-lubricated seed to the base of the upright needle. As the viscin dries, the seed is cemented to the shoot surface. To achieve infection, seeds usually must lodge on shoot segments that are less than 5 years old.

Red fir dwarf mistletoe and associated branch flagging caused by subsequent infection by the canker-causing fungus *Cytospora abietis* in Lassen Volcanic National Park

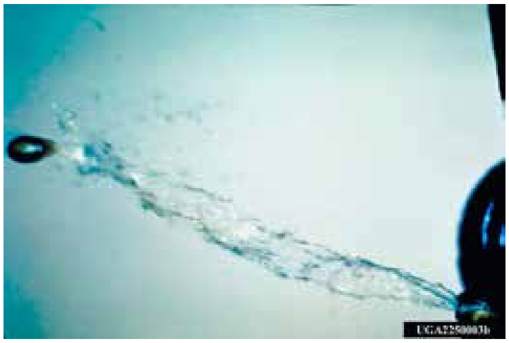
Photo: Bill Woodruff

Limber pine dwarf mistletoe in whitebark pine in the Russian Wilderness

Photo: Dave Schultz

Dwarf mistletoe disperses most effectively from overstory trees to smaller trees of the same species. Thus, spread tends to be most efficient in multi-aged stands of the same host tree species. Spread can also occur between nearby hosts of the same size, especially if they are within 13 meters (36 feet) of each other, but it is not nearly as rapid in this situation. Upward spread of dwarf mistletoe, especially within individual infected trees, is much less effective than downward spread. Susceptible branch tips are shielded by older needles when seeds are expelled from below. Upward spread of dwarf mistletoe is, on average, 30 cm (one ft) a year or less. If a tree is unable to put on that amount of growth annually, the mistletoe will be able to spread upward over time to the top of its crown.

Though most infection is from nearby trees or from already established plants in the same tree, birds and other animals can spread dwarf mistletoe over long distances when seeds stick to their coats or feathers. Thus, when they do occur, new infection centers tend to be established in areas favored by birds and other animals (in or around small openings etc.).



Example of hydrostatically controlled explosive mistletoe seed dispersal

Photo: Frank Hawksworth

The life cycle of a dwarf mistletoe, from infection to seed production, takes an average of 4 to 5 years. Infection is the equivalent of seedling establishment among terrestrial flowering plants. Successful infection by a dwarf mistletoe requires penetration of the host branch (which it does at the base of the needle) and the development of its root system, consisting of cortical strands and sinkers. Once the mistletoe plant is established, an incubation period of 2 to 5 years elapses before the young shoots appear, although a swelling at the point of infection usually proceeds shoot production by a year or more. Dwarf mistletoe plants begin to flower one or two years after the initial shoots appear. Pollination is accomplished by insects and wind. Most temperate species of mistletoe require one or more years for fruit to mature.

Damage and Importance: Dwarf mistletoes are considered among the most widespread and serious forest disease agents in many of the western states. Effects of dwarf mistletoes include the following:

Ponderosa pine heavily infected with western dwarf mistletoe, Lassen National Forest

Photo: Bill Woodruff

1. ***Reduction in growth***. Dwarf mistletoes are a major cause of growth loss and reduced vigor in coniferous forests of California. The degree of growth reduction depends on the intensity of infection and the location of the mistletoe in the tree. It ranges from essentially no measurable effect in lightly infected trees to a 30-60% reduction in growth in heavily infected trees.
2. ***Mortality***. Dwarf mistletoes can kill trees directly, but the most common situation is for dwarf mistletoes and insects, particularly bark beetles, working together to cause the death of heavily infected hosts. The length of time it will take for mistletoe to actually kill a heavily infected tree will vary depending on a number of factors including the size of the tree, its

vigor, the species involved, and whether insects, particularly bark beetles, are attracted to the tree. As a broad generalization though, trees are usually killed within 10-15 years once they become heavily infected throughout the crown. The dwarf mistletoe – bark beetle complex is one of the primary causes of tree mortality in California. In commercial forests, losses resulting from this pest complex can be as high as 2.1 billion board feet per year.

3. ***Predisposition to other pests***. Because of reduced vigor, trees heavily infected with dwarf mistletoe care more susceptible to attack by bark beetles and flatheaded borers. Dwarf mistletoe infections in red fir are often associated with infections by canker fungi, resulting in branch flagging. Bole swellings caused by dwarf mistletoe in true fir provide a means of entry for decay fungi.

4. ***Growth abnormalities***. Dwarf mistletoe infection causes visible changes in host growth and form, including brooming of branches and bole swellings.

5. ***Susceptibility to fire***. Dwarf mistletoe-infested stands are generally more flammable than healthy stands due to the large amounts of fuels arising from the accumulation of dead witches' brooms, fallen trees, and live brooms in the lower crowns. Because of these fuels, normally nondestructive fires can become stand replacing fires in stands with dwarf mistletoe. Dwarf mistletoe infected trees may be influenced by fire in several ways. Because infected trees have highly flammable witches' brooms and lower live crowns, a larger proportion of the crown of an infested tree is more likely to be scorched than the crown of a healthy tree. In addition, given equal amounts of scorch, the probability of survival of heavily infected trees may be less than half that of healthy trees.

6. ***Reduced seed Production***. Heavily infected trees produce fewer seeds and, therefore, make poor seed trees.

7. ***Product degrade***. Some product degrade results from bole infection and large knots produced by brooms.

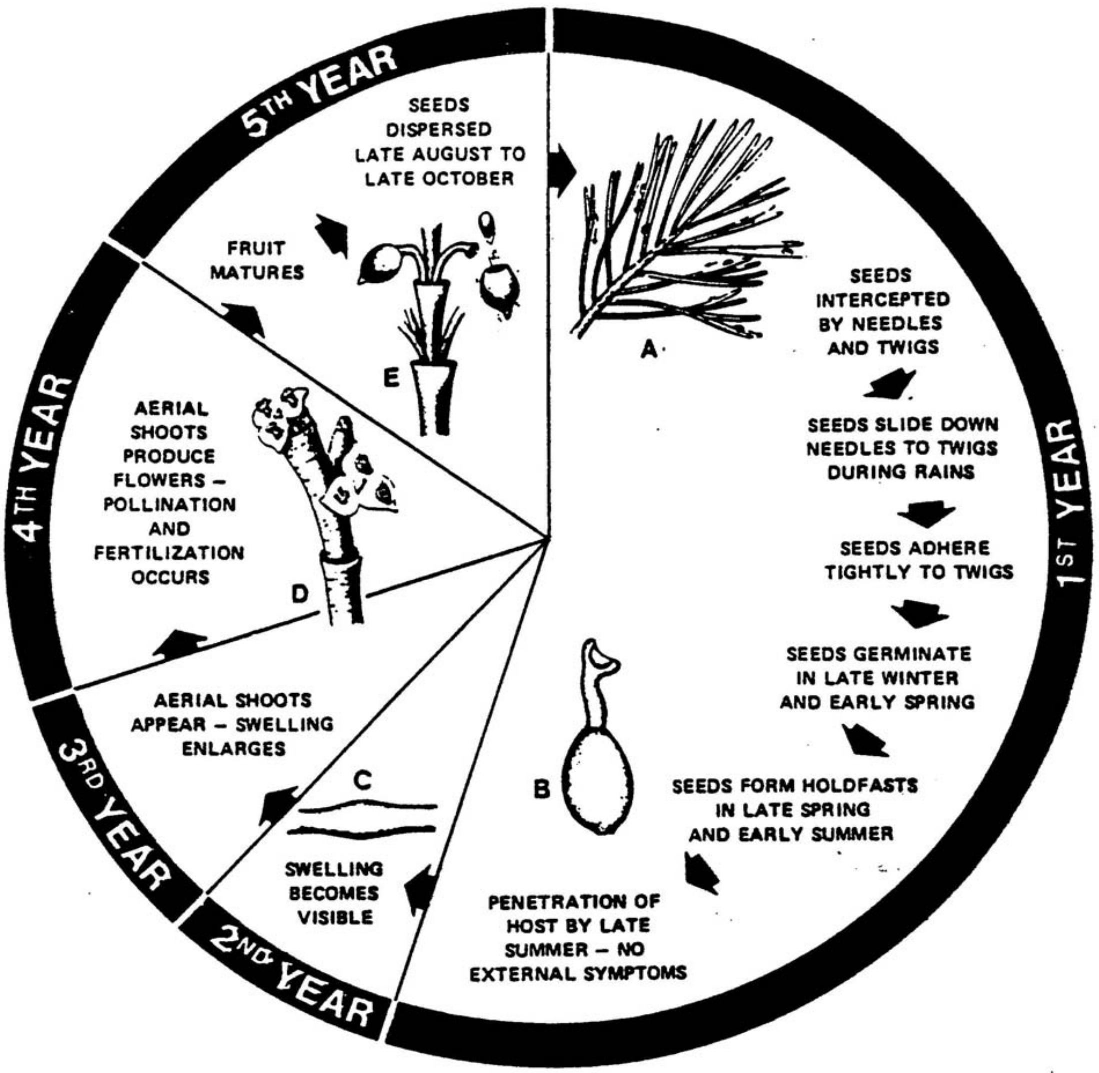


Figure 2. General disease cycle of dwarf mistletoes in California. Time may vary slightly between species and years.

Generalized life cycle of dwarf mistletoe:

A. Needle angles as they affect dwarf mistletoe seed movement.
B. A fully developed dwarf mistletoe seedling with holdfast.
C. Small branch swelling is the first indication of dwarf mistletoe infection.
D. Male (staminate) flowers of dwarf mistletoe.
E. Dwarf mistletoe seed discharge.

Dwarf Mistletoe Rating System: The expected effects of dwarf mistletoe on tree growth and survival have been demonstrated to be strongly correlated with infection severity or the amount of the crown colonized by mistletoe plants. Because of this strong correlation between severity and effects, it is important to have a standardized rating system to describe severity and to use it consistently. The Hawksworth 6-class dwarf mistletoe rating system (DMR) has become the standard for quantifying the severity of dwarf mistletoe infections.

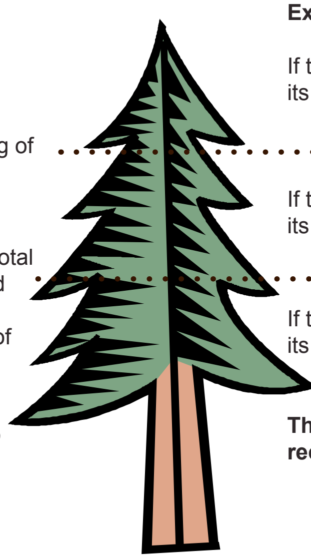
In the 6 class system, the live crown is visually divided into thirds. Each third is then assigned either a 0 (there is no mistletoe in that third); a 1 (½ or less of the branches are infected); or a 2 (more than ½ of the branches are infected). The ratings for each third are then tallied to obtain a total for the tree. This total is termed a DMR for an individual tree. DMR can range from 0 (meaning the tree is uninfected) to 6 (the tree is very heavily infected). An average stand or plot rating may be computed by calculating the average DMR rating of all live trees (infected and non-infected) by species.

Instructions

Step 1. Divide live crown into thirds.

Step 2. Rate each third separately. Each third should be given a rating of 0, 1 or 2 as described below.
(1) No visible infections is given a rating of 0.
(2) Light infections (1/2 or less of total number of branches in the third infected) is given a rating of 1.
(3) Heavy infection (more than ½ of total branches in the third infected) is given a rating of 2

Step 3. Finally, add ratings of thirds to obtain rating for total tree.



Example

If this third has no visible infections, its rating is (0).

If this third is lightly infested, its rating is (1).

If this third is heavily infested, its rating is (2).

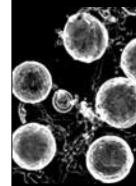
The tree is this example will receive a rating of 0 + 1 + 2= 3.

Figure 3. The six class dwarf mistletoe rating system (Hawkworth 1961)

The terms "spread" and "intensification" are commonly used to describe changes in mistletoe occurrence and severity levels. When a tree progresses from an initial DMR of 0 to a higher number it means that dwarf mistletoe has "*spread*" to that tree and it has become infected. When there is an increase in a DMR that is greater than 0 (DMR changes from a 2 to a 5 for example) it means that the infection has "*intensified*" in severity.

Ecological Roles: Dwarf mistletoes are believed to have co-evolved with their conifer hosts for over 5 million years. Obviously, neither has achieved the upper hand since both host and pathogen are presently thriving within many forest ecosystems. Historically, wildfire has been the most important single factor governing the abundance and distribution of dwarf mistletoes. Wildfires are frequently effective in limiting dwarf mistletoe populations because trees usually return to burned sites much faster than do dwarf mistletoes.

Within the natural balance between host, fire, and pathogen, dwarf mistletoe provides a source of vertical and horizontal diversity through gap creation, and production of snags, brooms and down woody material. Many species of mammals, birds, and arthropods can take advantage of the favorable structure mistletoe infection provides, while other species use mistletoe plants or host tissues associated with infection for food. The abundance of dwarf mistletoe is directly correlated with species diversity and bird density. There is also a strong positive relationship between the occurrence of dwarf mistletoe in an area and the number of snags used by cavity-nesting birds. Witches' brooms are commonly used for nest sites, roosting sites, and cover by



a number of bird species. The large mistletoe brooms on Douglas-fir are often used as nesting platforms by several owls (including the northern spotted owl), accipiters (including the coopers hawk, goshawk, and sharp-shinned hawk) and passerines. Brooms are also used for roosting cover by grouse. Use of mistletoe by wildlife and associated references are summarized in Hawksworth and Wiens, 1996.

While dwarf mistletoe infection centers provide enhanced diversity and habitat for wildlife, it should be remembered that heavy infection of a stand, without the sanitizing effect of fire or use of cutting practices which reduce the mistletoe, can result in a decline in habitat quality over the long term. The decline would occur ultimately as a result of the negative effect of heavy mistletoe on the production of large woody structure (living and dead) required by many wildlife species.

Management Strategies: Infestations of dwarf mistletoe not only affect timber values but also recreation, aesthetics, fire hazard, and wildlife habitat (both long and short term). ***Dwarf mistletoe lends itself to being managed silviculturally*** because it:

- *is easy to identify and measure*,
- *spreads relatively slowly*,
- *has a limited spread distance*,
- *is an obligate parasite,*
- *is relatively host specific*.

In most cases, the impacts of low and even moderate levels of dwarf mistletoe in a stand or landscape can be acceptable or even desirable, The key to successfully avoiding the most serious effects of mistletoe on tree growth, mortality and ecosystem degradation depends on avoiding stand conditions that lead to unacceptably heavy levels of infection..

There are a variety of silvicultural options that can be used to manage undesirable effects of dwarf mistletoe. These fall into 6 general groups:

1. ***Sanitation cuts***. Infected trees are removed (or killed) to eliminate or reduce the spread of mistletoe to insignificant levels. The most drastic version of this practice is a clear cut.
2. ***Thinning to outgrow the mistletoe***. Trees are spaced to promote height growth that is greater than the upward spread of the mistletoe. Trees grow faster than the mistletoe can spread upward, proportionally less of their crowns are infected, and heavy infection levels are never achieved. This technique works well in single-storied stands, especially on good sites.
3. ***Favoring alternative species***. By planting or featuring species that the dwarf mistletoe infesting the site cannot attack, the mistletoe is unable to spread into additional trees.
4. ***Converting to stand structures that are not conducive to dwarf mistletoe.*** Stands with more than one canopy level favor the rapid proliferation of mistletoe. By converting to a single canopy structure (at least for the species that is infected), the spread of mistletoe is greatly slowed because, once accomplished, the trees only have to deal with horizontal and vertical spread; both of which are much less rapid and effective than spread from an overstory source to a susceptible understory.
5. ***Creation of host-free buffer strips.*** Host-free buffer strips can be used to prevent dwarf mistletoe from re-entering a control area or, when the parasite is not eliminated, from leaving the site. Buffer strips should be at least as wide as the height of the highest mistletoe plants in the adjacent infested stand. Examples of existing buffers include meadows, roads, rivers, clearings, and aggregations or plantings of non-host

trees. Construction of new roads, structures, or campsites can also be used to create buffer zones and eliminate pockets of heavily infected trees.

6. ***Individual tree treatments (broom removal and/or sanitation pruning)***. Broom pruning, in which dwarf mistletoe brooms are removed, is done to extend tree life and maintain individual trees on a site as long as possible. This is most often used in areas that have little or no understory, and should not be done if less than 30% of the live crown will be left after treatment. Because of latent infections, the treatment will not eliminate dwarf mistletoe from the stand or prevent future spread.

Species of *Arceuthobium* in California

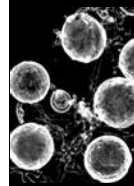
Table 4. Species of *Arceuthobium* in California

Species	Common Name	Principal Hosts
A. abietinum f. sp. *concoloris*	White Fir Dwarf Mistletoe	White fir, Grand fir
A. abietinum f. sp. *magnificae*	Red Fir Dwarf Mistletoe	Red fir
A. abietinum ssp. *wiensii*	Wiens' Dwarf Mistletoe	Red fir, Brewer spruce, occ. White fir
A. americanum	Lodgepole Pine Dwarf Mistletoe	Lodgepole pine, occ. Ponderosa pine
A. californicum	Sugar Pine Dwarf Mistletoe	Sugar pine
A. campylopodum	Western Dwarf Mistletoe	Ponderosa pine, Jeffrey pine, Coulter pine, occ. Lodgepole pine
A. cyanocarpum	Limber Pine Dwarf Mistletoe	Whitebark pine, Limber pine, occ. Foxtail pine and Western white pine
A. divaricatum	Pinyon Dwarf Mistletoe	Pinyon Pine
A. douglasii	Douglas-fir Dwarf Mistletoe	Douglas-fir
A. littorum	Coastal Dwarf Mistletoe	Monterey pine, Bishop pine
A. monticola	Western White Pine Dwarf Mistletoe	Western white pine, occ. Sugar pine
A. occidentale	Gray Pine Dwarf Mistletoe	Gray pine, sec. Knobcone pine, and Coulter pine, occ. Ponderosa pine and Jeffrey pine
A. siskiyouense	Knobcone Pine Dwarf Mistletoe	Knobcone pine, Jeffery pine, rarely Ponderosa pine, and Shore pine
A. tsugense ssp. *mertensianae*	Mountain Hemlock Dwarf Mistletoe	Mountain hemlock
A. tsugense ssp. *tsugense*	Western Hemlock Dwarf Mistletoe	Western hemlock

Sanitation branch pruning involves the removal of all lower branches, both healthy and diseased, up to and including the second whorl of branches above the highest visible mistletoe infection. This is done in order to reduce or eliminate dwarf mistletoe seed in the stand and to improve tree vigor. This treatment should only be done on trees with a DMR of 3 or less, or a rating of 4 and no mistletoe in the upper one-third of the crown. It should not be done if less than 30% of the live crown will remain after treatment or if the tree will be exposed to continued infection from adjacent infected trees. Because of latent infections, at least two treatments are generally needed to eliminate the pathogen from the tree.

Techniques employed depend on individual situations. Management objective, stand age, structure, density, species composition, number of years to harvest, and the severity and distribution of the mistletoe need to be understood and considered in devising an appropriate management strategy.

Predictive models like FVS (Forest Vegetation Simulator) are available to help evaluate the outcomes of various silvicultural treatments over time in stands with dwarf mistletoe.



References

Beatty, Jerome S., and Robert L. Mathiasen. 2003. Dwarf mistletoes on ponderosa pine. USDA Forest Service, Forest Insect and Disease Leaflet 40. 8 p.

Bennetts, R.E., White, G.C., Hawksworth, F.G. 1992. The indirect effects of dwarf mistletoe on bird communities in Colorado ponderosa pine forests. In: Muir, J.A., comp. Proceedings, 39th Annual Western Internation forest Disease Work Conference; 1991 August 5-9; Vernon, BC. Victoria: British Columbia Ministry of Forests, Silviculture Branch: 14-17.

Harrington, M.G; and Hawksworth, F.G. 1990. Interactions of fire and dwarf mistletoe on mortality of southwestern ponderosa pine. In: Krammes, J.S., tech. Coord. Effects of fire management of southwestern natural resources: Proceedings of symposium; 1988 November 15-17; Tucson, AZ. General Technical Report RM-191. Fort Collins, CO U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 234-240.

Hawksworth, F.G. 1961. Dwarf Mistletoe of Ponderosa Pine in the Southwest. USDA Technical Bulletin No. 1246. 112 p.

Hawksworth, F.G. 1977. The 6-class dwarf mistletoe rating system. General Technical Report RM-48. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 7 p.

Hawksworth, F.G. and Scharpf, R.F. 1984. Biology of Dwarf Mistletoes: Proceedings of the Symposium. April 8, 1984, Fort Collins, CO. USDA For. Serv. Gen. Tech. Rpt. RM-111. 131 p.

Hawksworth, F.G., and Scharpf, R.F. 1978. Literature on the dwarf mistletoes: damage and control. In: Proceedings , symposium on dwarf mistletoe control through forest management; 1978 April 11-13; Berkeley, CA. General Technical Report PSW-31, U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest Experiment Station: 178-179.

Hawksworth, F.G. and Wiens, D. 1972. Biology and Classification of Dwarf Mistletoes (*Arceuthobium*). USDA For Serv. Agric. Handbook No. 401. 234 p.

Hawksworth, F.G, and Wiens, D. 1996. Dwarf Mistletoes: Biology, Pathology, and Systematics. B.W. Geils, technical editor, R.G. Nisley, managing editor, US Department of Agriculture Handbook 709. Washington DC. 410 p.

Hudler, G., Oshima, N., and Hawksworth, F.G. 1979. Bird dissemination of dwarf mistletoe on ponderosa pine in Colorado. American Midland Naturalist. 102(2): 273-280.

Mathiasen, R.L. and Daugherty, C.M. 2009. *Arceuthobium abietinum* subspecies *wiensii*, a new subspecies of fir dwarf mistletoe (Viscaceae) from northern California and southern Oregon. Madrono. 56: 118-126.

Mathiasen, R. L., and S. C. Kenaley. 2014. A morphometric analysis of dwarf mistletoes in the *Arceuthobium campylopodum-occidentale* complex (Viscaceae). Madroño 62: 1-20.

Mathiasen, Robert, John Pronos, and Jerome Beatty. 2005. Dwarf mistletoes on sugar pine and western white pine. USDA Forest Service, Forest Insect and Disease Leaflet 113. 11 p.

Pronos, John, Robert L. Mathiasen, and Jerome S. Beatty. 2004. Gray pine dwarf mistletoe USDA Forest Service, Forest Insect and Disease Leaflet 179, 7 p.

Scharpf, R.F. and Parmeter, J.R., tech. coords. 1978. Proceedings of the Symposium on Dwarf Mistletoe Control Through Forest Pest Management, April 11-13, 1978, Berkeley, CA. USDA For. Serv. Gen. Tech. Rpt. PSW-131. 190 pp.

Scharpf, R.F., Smith, R.S., and Vogler, D. 1987. Pruning dwarf mistletoe brooms reduces stress on Jeffrey pines, Cleveland National Forest, California. Research Paper PSW-186. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 7 p.

Scharpf, R.F., Smith, R.S., and Vogler, D. 1988. Management of western dwarf mistletoe in ponderosa and Jeffrey pines in forest recreation sites. USDA Forest Service, General Technical Report PSW-103. 11p.

Tinnin, R.O., Hawksworth, F.G., and Knutson, D.M. 1982. Witches' broom formation in conifers infected by *Arceuthobium spp*.; an example of parasitic impact on community dynamics. American Midland Naturalist. 107: 351-359.

Vogler, D.R. and Scharpf, R.F. 1981. Dwarf Mistletoe-Related Mortality of Ponderosa and Jeffrey Pines at Five Campgrounds in California and Nevada. USDA-Forest Service, Pacific Southwest Region, For. Pest Mgmt. Rpt. No. 8-18. 22 pp.

Root Diseases

Root pathogens are extremely important natural disturbance agents in western forest ecosystems. Root disease organisms kill host cambium, disrupt water conducting tissue, decay wood, or cause some combination of these effects. Root pathogens can directly kill host trees; but often death results from windthrow or bark beetles that attack disease-weakened trees.

The four most important root diseases in California are Heterobasidion root disease, black stain root disease, Port-Orford-cedar root disease and Armillaria root disease. These diseases are caused by several species of Basidiomycete fungi and one Oomycete. With the exception of *Phytophthora lateralis*, the lone oomycete and the cause of Port-Orford-cedar root disease, all of the root disease organisms are native pathogens that evolved with their hosts. Some root pathogens are favored by conditions associated with low host vigor. Others are able to cause infection regardless of tree condition. Some are very host specific, while others affect a wide range of hosts. Susceptibility to root disease pathogens often varies with host age or with geographic location.

Root disease can alter forest structure, composition, function, and yield. Root disease can create openings (gaps or root disease pockets) in the forest of various sizes. These gaps can subsequently be colonized by a variety of species of forbs, shrubs, and trees. If susceptible tree species colonize root disease pockets, they will eventually be infected and the pathogen will survive on the site. If immune species colonize root disease pockets, the pathogen dies out after many years or decades, and eventually susceptible species may once again grow on the site. If intermediately susceptible tree species colonize the root disease pockets, the root disease may survive and continue to influence vegetative development according to relative species susceptibilities. Intermediately susceptible hosts may suffer reduced growth, increased levels of butt decay, increased chance of windthrow, and some mortality.

Root diseases influence stand composition by selectively killing some species and allowing others to survive. Stocking levels may be reduced in areas in a stand depending on the distribution of the pathogen and the tree species present. Species diversity may increase or decrease. Production of special forest products such as berries, boughs, and mushrooms may increase in gaps. Root diseases influence stand structure by killing large trees, slowing their growth and limiting the survival of replacement trees. By killing large trees, root diseases create

Aerial photograph of root disease patches; ringworm pattern in an otherwise uniform canopy

Photo: Ralph Williams

snags that are extremely important for wildlife. However, extensive decay in these snags allows them to stand for only a short period of time relative to trees killed by other agents. Root diseases create down woody material that is important for wildlife habitat, soil water holding capacity, and nutrient cycling.

Root diseases are often difficult to detect and sometimes impossible to confirm. Symptoms can be subtle and signs non-existent. Trees with root disease tend to die slowly, especially when older. Mortality may occur in groups or in scattered individuals. Typically, trees with root diseases exhibit several similar aboveground symptoms. Infected trees decline gradually with symptoms progressing from the bottom of the live crown upwards, and from the bole to the tips of live branches. In other words, the crown dies from the bottom-up and from the inside-out. Needle retention is poor and the needles may be shorter than in healthy trees. This gives the crowns the appearance of being thin and off-color. During stand examinations and inventories, trees with root disease symptoms and diagnostic signs are recorded as infected trees. In addition, asymptomatic trees within 30-feet (10 m) of known root diseased trees are usually also considered to be infected. Identifying trees in the close proximity of known infected trees allows for data collection on those trees that do not yet show signs or symptoms but whose probability of being infected is high.

Most root disease pathogens spread when the roots of susceptible uninfected trees directly contact the roots of diseased trees. Airborne spores, insect vectors, short distance growth of fungi through the soil and movement of infective propagules in soil are additional mechanisms that facilitate the spread of individual root diseases.

The Western Root Disease Model (WRDM) is a tool that can be used to project root disease impacts on forest stands. The WRDM is an extension to the Forest Vegetation Simulator. It can model effects of both Armillaria and Heterobasidion root diseases. Using stand inventory information describing current conditions, the model simulates spread from tree to tree, growth loss, and mortality. It also simulates bark beetle activity where appropriate.

Table 5. Comparison of Four Root Diseases in California

Comparison of Four Root Diseases in California

	Heterobasidion Root Disease		Black Stain Root Disease	Armillaria Root Disease	Port-Orford-Cedar Root Disease
Pathogen	*H. irregulare*	*H. occidentale*	*Leptographium wageneri*	*Armillaria spp.*	*Phytophthora lateralis*
Hosts	All Conifers		Ponderosa pine, Jeffrey pine, Douglas-fir, singleleaf pinyon pine	All conifers, oaks	Port-Orford-Cedar, Pacific yew
Distribution	**Pines** East side pine, low elevation w side pine, mixed conifer	**True Firs** Fir stands statewide	Southern Cascades and northern Sierra Nevada (ponderosa and Jeffrey pines); southern California (singleleaf pinyon pine); throughout the range of Douglas-fir (Douglas-fir)	Conifer stands with oaks	Northwestern California - Smith River drainage, Orleans RD, Siskiyou Wilderness Area, Willow Creek west of the town Willow Creek, main stem of the Sacramento River between Lake Shasta and Lake Siskiyou
Damage	Root killing, mortality	Growth reduction, root rot, mortality, windthrow	Mortality	Mortality near oaks or oak stumps	Mortality
Disease Cycle	Stump invasion, root transmission	Stump & wound invasion, root transmission	Insect transmission, root transmission	Root transmission, buildup inoculum on dead oak roots, rhizomorphs	Water and soil transmission, root transmission
Field I.D.	Conks, resin in roots, cambial symptoms	Conks, decay (laminated)	Black stain follows annual rings, streaks upwards from roots	Rhizomorphs; mycelial fans; resinous, flared base of conifers; dead oaks or stumps; yellow, stringy, wet decay	Entire crown fades at once, brown stain at root collar, infestation follows watercourse
Prevention/ Control	Borax stump treatment. Species conversion (hardwoods).	Borax stump treatment. Species conversion (hardwoods and pines)	Heavy logging to recover mortality volume. Properly timed thinning to increase vigor and reduce insect vectors. Species conversion.	Avoid killing oaks near high-value conifers	Reduce spread/intensification through sanitary practices, control road access in wet season, eradicate host in new infestations, plant resistant POC
Notes	Creates special hazards in incense-cedar due to decay-related windthrow. Also, see section on use of borax, FSH 3409.11 Chapter 60, R5 Supplement 3409.11-2010-1 (2/09/10)		Throughout the Region, centers often originate from disturbance	All Armillaria spp. can invade trees killed by other causes	Use genetically resistant seed

Heterobasidion Root Disease (*Heterobasidion* spp.) (*Fomes, Heterobasidion*)

Hosts: *H. irregulare* - Pines, incense cedar, western juniper, Pacific madrone, manzanita
H. occidentale – true firs,, giant sequoia, hemlocks. Douglas-fir is a listed host, but is rarely infected in California.

Distribution in California: Statewide

Characteristics: A Heterobasidion root disease infestation, especially of pine, is characterized by group killing, with the oldest mortality at the center and the most recent dead and dying trees at the margin. Such disease centers usually develop around infected stumps. Infected trees may also be infested with bark beetles. Crowns of living, infected trees are chlorotic and thin. Symptoms are usually expressed from the bottom and inside of the crown up and outward. Trees usually are stunted or exhibit reduced growth, especially in the terminal shoots. Shortened needles and "lion's-tailing" (needles only retained at the tip of the branch shoots) may also be present. In pines, the roots and root collar have several symptoms:

H. occidentale conks in white fir stump

Photo: Pete Angwin

- Easy separation of bark and wood
- A streaking of the wood surface with darker brown lines
- Small silver to white flecks on the surface of the inner bark
- Heavy resin accumulation in the wood of pines is common

Wood decayed by *Heterobasidion* spp. is straw yellow, stringy or laminated, and may have small black flecks.

The fungus can be readily identified in the field if fruiting bodies are present in or on infected trees or stumps. Conks (fruiting bodies) on standing trees are occasionally located in the duff layer at the base of the tree. More commonly, conks can be found in internal cavities of old decayed stumps. Conks are variable in size and shape and have a light gray to brown upper surface and a creamy white to light brown lower pore surface. Tiny conks (called "popcorn conks") can sometimes be found growing under bark or on roots of infected trees. These are sometimes easily found by pulling up dead seedlings near decayed stumps and inspecting the roots.

Disease Cycle: Heterobasidion root disease infection centers start when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds on the butt. Fresh basal wounds on species other than true fir are rarely colonized. The fungus grows down the stump into the roots and then spreads through root contacts into the root systems of adjacent live trees, resulting in the formation of enlarging disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but is more frequently confined to the

H. occidentale conk and laminated decay from inside a white fir stump

Photo: Pete Angwin

heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss, or failure at the roots.

Heterobasidion root disease infection center in ponderosa pine

Photo: Danny Cluck

Heterobasidion root disease in western North America is caused by two *Heterobasidion* species: *H. occidentale*, and *H. irregulare*. These species have distinct differences in host specificity. To date, all isolates of *Heterobasidion* from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense-cedar, western juniper, pinyon pine, Pacific madrone and manzanita are *H. irregulare*. Isolates from true fir, Douglas-fir, hemlocks and giant sequoia are *H. occidentale*.

Data suggest that infection of living trees is host specific, but saprophytic colonization of stumps is not. *H. irregulare* has been found to colonize stumps of hosts that are specific to *H. occidentale* and vice versa. However, while *H. occidentale* has been observed to pass from infected pine stumps into live fir, but it is very rare for *H. irregulare* to pass from infected fir stumps into pine. The fungus may survive in infected roots or stumps for many years. Host conifer seedlings and saplings growing near infected stumps often die shortly after their roots contact infected roots in the soil.

Invasion of freshly cut stump surfaces by germinating spores is a critical stage in the disease cycle. Fungal fruiting bodies (conks) produce spores which disseminate throughout the year, but *Heterobasidion* spp. are dependent on favorable environmental conditions for successful germination and establishment. Spores are inactivated by ambient temperatures of 113º F (45ºC) and mycelium in wood is killed after exposure for one hour at 104º F (40ºC). In eastside pine on the Lassen National Forest, lethal temperatures reach above 40ºC in the top 6 inches of 6-inch diameter stumps when exposed to direct sunlight for several days in the average summer. Temperatures do not approach the lethal range in larger size classes of stumps.

Stumps are susceptible to infection immediately after cutting. Ponderosa pine and coast redwood stumps remain susceptible to infection for 2 to 4 weeks. The decrease in susceptibility with time is probably a result of colonization of the stumps by microorganisms that out-compete *Heterobasidion* spp.under saprophytic conditions.

Heterobasidion growth in wood depends on temperature and extent of injury. After germination, vertical growth into pine stumps averages 3 inches/month (7.0 cm/mo.) from October through May and 5 to 6 inches/month (12 to 15 cm/mo.) from June to October

Damage and Importance: Heterobasidion root disease is one of the most important conifer diseases in California. Current estimates are that the disease infests about 2 million acres of commercial forest land in California resulting in an annual volume loss of 19 million cubic feet.

Blowdown exposed Heterobasidion root disease on the Plumas National Forest

Photo: Bill Woodruff

Potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of production on the site, and, in recreation areas, depletion of vegetative cover and increased probability of tree failure and hazard. In recreation areas, *Heterobasidion*-infected trees are often extremely hazardous, causing death or injury to visitors, and damage to permanent installations and property. Ecologically, *Heterobasidion* spp. effectively decays wood in the butt and roots of trees and recycles nutrients. It creates stand openings, enhances diversity, provides wildlife habitat, and alters forest structure, composition, and succession.

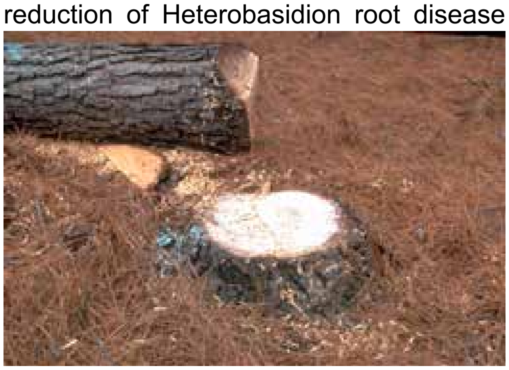
Heterobasidion root disease occurs on a wide range of woody plants. The disease affects a wide range of western conifers; hardwoods are generally resistant or immune. All National Forests in California have reported finding it. Incidence is particularly high on Jeffrey pine in southern California recreation sites and on Jeffrey and ponderosa pine in eastside pine type forests. The disease, endemic in the red and white fir forest types, is associated with one-fifth or more of the true fir mortality in the forests surveyed in northern California.

Approximately 1.4 million acres of ponderosa pine and Jeffrey pines in California are infested with Heterobasidion root disease. *H. irregulare* girdles pine trees at the root crown within two to six years after initial infection, resulting in tree mortality.

Approximately 600,000 acres of true fir in northern California are infested with Heterobasidion root disease. In true firs, the fungus causes root and butt rot more often than mortality, at least in larger trees. This may result in windthrow and increased susceptibility to bark beetle attack. It is not known how long infected true fir trees will survive. Since uprooted true fir trees with *Heterobasidion*-decayed roots are commonly observed in infested stands, it is assumed that infected true fir trees can live as long as they remain windfirm and resilient to being overcome by fir engraver beetles (*Scolytus ventralis*).

Heterobasidion root disease in incense-cedar and true fir is a problem in recreational areas because these trees commonly have extensive decay in the roots while alive, sometimes without visible symptoms of root disease. Although not often observed, living ponderosa and Jeffrey pine trees in recreation areas have failed because their roots were extensively decayed. Whenever Heterobasidion root disease is known to be present in recreation areas, serious consideration should be given to potential hazards.

Management Strategies: The goal of Heterobasidion root disease management in California is to reduce resource losses to levels which are economically, aesthetically, and environmentally acceptable when measured against the objectives of the resource manager. It is possible to reduce the impact of Heterobasidion root disease through detection, evaluation, prevention, and suppression. These activities must progress in a planned, timely sequence for successful reduction of Heterobasidion root disease impacts. Detection and evaluation in individual stands are normally necessary before undertaking prevention and suppression action.

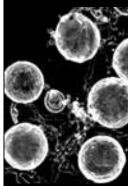


Heterobasidion root rot; Borax stump treatment

Photo: Paul Mistretta

In general, prevention is the most desirable means of reducing lossed caused by Heterobasidion root disease. Once the pathogen becomes established, in a stand, there are no inexpensive procedures for directly suppressing the disease. One of the most effective and economical methods of preventing the introduction of *Heterobasidion* spp. to uninfested stands is the application of an EPA-registered borate fungicide to freshly-cut stumps. Two compounds are currently registered for this purpose- Sporax® (sodium tetraborate decahydrate, EPA Reg. No. 2935-501) and Cellu-Treat (disodium octaborate tetrahydrate, EPA Reg. No. 464405-8);. In order to be effective, Sporax or Cellu-Treat must be applied no more than 4-24 hours after the tree is felled. When properly applied, studies indicate at least a 90% efficacy rate in preventing stump infection.

In developed recreation and high value sites, early recognition and removal of hazardous *Heterobasidion*-infected trees is critical, and will greatly improve chances of preventing future damage with minimal site deterioration. When infection levels are high, consider the removal of all host trees and conversion to hardwoods and/or non-host conifers. On Forest Service land in the Pacific Southwest Region, Forest Service Manual and Handbook direction (Region



5 Forest Service Manual Supplement 2303.14 (6/15/1992) and Region 5 Forest Service Handbook Supplement 3409,11- Chapter 60 (6/10/2013)) mandates the treatment of freshly-cut conifer stumps with an EPA-registered borate compound. Manual direction specifies that all conifer stumps be treated, while the more recent Handbook direction specifies the treatment of stumps 3 inches (8 cm) or larger. It is anticipated that the Manual direction will be updated to match the Handbook.

Management Strategies – Pine: Treat all freshly cut stumps in recreation areas and high-value sites three inches (8 cm) and larger with an appropriate EPA-registered borate compound such as Sporax or Cellu-Treat. In all other areas, the appropriate line officer, is responsible for the decision to treat or not treat freshly cut conifer stumps. This decision is best made in consultation with a US Forest Service Forest Health Protection pathologist or a CALFIRE pest management specialist. Treatments are best considered on an individual stand basis, utilizing information available for the specific situation and stand in question. This information should include:

- The objectives and management direction for the stand.
- The level of Heterobasidion root disease currently in the stand or in nearby similar stands, determined by an examination of stumps for evidence of *H. irregulare* and/or indications of infection in living trees.
- An estimate of the cost-effectiveness of the treatment.

In eastside pine or mixed conifer type stands in the general forest (forest stands that are not in recreation area or high-value area), and especially in areas where surveys have indicated light or moderate level of Heterobasidion root disease, Region 5 Forest Service Handbook direction recommends treatment of conifer stumps 14 inches (36 cm) or larger in outside bark diameter. In addition, in fire salvage areas, stumps of conifers that have been affected by fire that are 14 inches (36 cm) or larger and have been dead less than 18 months should also be treated (2450/3400 letter from Regional Forester, May 15, 2013) If it is not possible to determine when the tree died, then stumps should be treated if any needles (green or brown) were present on the tree when it was cut.

Management Strategies – True Fir: Treat all freshly cut conifer stumps 3 inches (8 cm) or larger in developed recreation areas or high value sites with Sporax® or Cellu-Treat; consider conversion to non-host trees.

In commercial timber stands, we cannot at this time recommend treatment of fir stumps with Sporax®, nor can we recommend not treating. This is because the exact role of true fir stumps in spreading the Heterobasidion root disease is not known. True fir can be infected through fire and mechanical wounds on the butt in addition to stumps. Therefore, the roots of a true fir tree may be infected prior to cutting which would negate the benefit of treating its stump with Sporax® or Cellu-Treat. However, if a group of true fir trees appear to be free of Heterobasidion root disease, stump treatment, particularly for stumps greater than fourteen inches in diameter, may be warranted. The treatment decision should lie with the appropriate line officer who has been fully briefed on the specific situation in the particular stand in question. Again, it is best if Forest Health Protection pathologists or CALFIRE pest management specialists are consulted and provide assistance.

In addition to the general information above, the following information applies to *H. occidentale* infection in true fir (not pine) stands, and may be considered when deciding whether or not to treat stumps with Sporax or Cellu-Treat:

- *H. occidentale* can enter true fir in a stand by means other than through freshly cut stump surfaces
- True fir stands are often infested with *H. occidentale* before harvest entry. This infestation and the level of infection may be difficult to detect and determine because

infection in true fir usually results in a heartrot with no above ground crown symptoms produced.

- Sporax® or Cellu-Treat treatment of true fir stump surfaces will not prevent the entrance of *H. occidentale* into the root systems of true fir through fire or mechanical wounds, nor will it eradicate existing root or stump infections present at the time the tree was cut.
- The spread of *H. occidentale* by root contact from true fir to pine is rare. Therefore, even if stump surface infection of true fir occurs, it probably will not affect adjacent pines in the stand.

Management Strategies – Incense Cedar: Since the primary impact of Heterobasidion root disease in incense-cedar is one of hazard, the primary control strategy is that of determining failure potential. The potential for early failure can be estimated based on the amount of decay in supporting roots, as indicated by crown characteristics.

Three crown characteristics, which are influenced by root decay, are rated as follows:

1. Percent live crown – the amount of the total crown that has live limbs. Estimate to the nearest 10 percent

2. Crown vigor – condition of the live crown as indicated by the loss of interior foliage and the dying of secondary and tertiary limbs. Rate as indicated in the following table:

	Rating
Healthy crown	4
Lower 1/3 declining	3
Lower 2/3 declining	2
Whole crown declining	1

3. Crown top shape – the silhouette of the top of the crown. Rate as indicted in the following table:

	Rating
Pointed	3
Rounded	2
Flattened	1

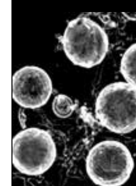
Enter the ratings into the following equation, then use the table on the following page to estimate root decay:

Potential for Early Failure = 6.5 - .02a - .58b - .45c where

a =	percent live crown
b =	crown vigor rating
c =	crown top shape rating

Estimating root decay from early failure potential:

Estimated Potential for Early Failure	Estimate of Amount of Decayed Support Roots	Root Decay Class
< 1	0	None
1 – 2.99	1 – 40%	Low
3 – 3.99	41 – 80%	Moderate
4 – 6.50	81 – 100%	High



References

Byler, J.W.; Estes, K.M.; Srago, M.D. 1978. Application of a decision tool for annosus root disease prevention to three timber sales in northeastern California. USDA Forest Service, Pacific Southwest Region, Unnumbered Report. 8 p.

DeNitto, G.A. 1985. Evaluation of *Fomes annosus* in precommercially thinned pine stands on the Lassen National Forest. USDA Forest Service, Pacific Southwest Region, Report Number 85-36. 2 p.

DeNitto, G.A. 1988. Evaluation of annosus root disease on McCloud Ranger District. USDA Forest Service, Pacific Southwest Region, Northern California Shared Service Area, Redding, Unnumbered Report. 3 p.

Graham, D.A. 1971. Evaluation of borax for prevention of annosus root rot in California. Plant Disease Reporter 55: 490-493.

Kliejunas, J.T. 1985. A biological evaluation of pests associated with the shear and stack technique for precommercial thinning on the Doublehead Ranger District, Modoc National Forest. USDA Forest Service, Pacific Southwest Region, San Francisco, Report Number 85 18. 8 p.

Kliejunas, J.T. 1986. Incidence of *Fomes annosus* stump infection on the Doublehead and Devils Garden Ranger Districts, Modoc National Forest. USDA Forest Service, Pacific Southwest Region, Report Number 86-21. 4 p.

Kliejunas, J.T. 1989a. Borax stump treatment for control of annosus root disease in the eastside pine type forests of northeastern California. p. 159-166. In: Otrosina, W.J. and Scharpf, R.F., tech. coordinators, Proceedings of the symposium on research and management of annosus root disease (*Heterobasidion annosum*) in western North America: April 18-21, 1989; Monterey, CA. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Gen. Tech. Rep. PSW-116. Berkeley, CA.

Kliejunas, J.T. 1989b. Incidence of *Heterobasidion annosum* stump infection in eastside pine type stands on the Plumas and Tahoe National Forests. USDA Forest Service, Pacific Southwest Region, San Francisco, Report Number 89-16. 9 p.

Meinecke, E.P. 1914. Forest tree diseases common in California and Nevada. A manual for field use. U.S. Department of Agriculture, Washington, D.C. 67 p.

Pronos, J.; Harris, J. 1991. Incidence of annosus root disease stump infection in eastside pine type stands on the Inyo National Forest. USDA Forest Service, Pacific Southwest Region, South Sierra Shared Service Area, Sonora, Report No. C90-14. 7 p.

Schmit, C.L., J.R. Parmeter and J.T. Kliejunas. 2000. Annosus root disease of western conifers. USDA For. Serv., For. Ins. & Dis. Leaflet 172, 9p.

Smith, R.S. Jr. 1983. Diseases of eastside pine types. p. 79-81. In: Proceedings of the symposium on management of the eastside pine type in northeastern California; June 15-17, 1982; Susanville, CA: Northern California Society of American Foresters.

Smith, R.S. Jr.; Bega, R.V.; Tarry, J. 1966. Additional hosts of *Fomes annosus* in California. Plant Disease Reporter 50: 79-81.

Wagener, W.W.; Cave, M.S. 1946. Pine killing by the root fungus *Fomes annosus* in California. Journal of Forestry 44: 47-54

Armillaria Root Disease (Shoestring Root Rot) (*Armillaria* spp.)

Hosts: Conifers and Hardwoods

Distribution in California: Statewide, in forest, agricultural, and urban situations

Characteristics: *Armillaria* spp. has long been recognized as both the cause of a major root disease and as a widespread forest saprophyte. These two roles of *Armillaria* spp. have done much to cloud our understanding of the role of this fungus in the forest ecosystem and our judgments of its importance. Recent studies on taxonomic studies on the *Armillaria* spp*.* complex have shed light on this situation. What was once thought to be a single species (*A. mellea*) is now known to be a complex of morphologically similar biological species, each with its own pathogenicity and host range. California has four known *Armillaria* species: *A. mellea* (sensu stricto), *A. gallica*, *A. nabsnona*, and NABS X (North American Biological Species Number Ten). *A. ostoyae*, which is the most highly pathogenic species of *Armillaria*, does not occur in California.

Mycelial fans of *Armillaria* under bark of lodgepole pine

Photo: Borys Tkacz

Armillaria mellea is the most virulent, and the widely-distributed species of Armillaria in California. It's common in most regions of the state dominated by developed areas, such as the Central Valley, the San Francisco Bay area, and Los Angeles, which were once largely occupied by susceptible oak and other hardwood species. While *A. mellea* does cause mortality in California forests, large disease centers are rare. Significant damage is more common in orchards and vineyards than in native forest habitats, and is particularly damaging on irrigated sites previously inhabited by hardwood forests.

Armillaria gallica occupies a variety of forest types and is found in many regions of California, including the Coastal mountains, the Sierra Nevada, and the southern Cascades. It is extremely rare in developed areas. A. gallica is considered to be a weak pathogen that preferentially attacks stressed trees. While it is sometimes capable of attacking healthy live hosts, it occurs more frequently as a saprophyte on dead tissue or as an epiphyte on the surface of live roots.

Armillaria nabsnona and NABS X appear to have very limited ranges in California. *A. nabsnona* appears to exist mainly as a saprophyte on dead understory hardwoods in north coast redwood forests. NABS X is considered to be a weak pathogen of conifers, and appears to be restricted to high elevation areas of the southern Cascades.

Rhizomorphs of *Armillaria* on ponderosa pine

Photo: Bill Woodruff

Symptoms and Signs: An Armillaria root disease center is characterized by individual or group killing. The disease in living trees is usually associated with oak stumps and dead oaks, and is usually restricted to the zone of hardwood root influence. Centers do not enlarge indefinitely.

Crown symptoms are similar to those described for *Heterobasidion* spp. Infected pines may produce an abundance of resin that accumulates in the wood or surrounding soil. Decayed wood is yellow, stringy, often water-soaked, and often has fine black zone lines.

Rhizomorphs and mycelial fans, which the fungus produces, are of great aid in diagnosis. Rhizomorphs are black, shoestring-like structures that can be found growing from the roots, between the bark and wood, or in the soil. Mycelial fans are white, leathery sheets of fungus growth, which can be found between the bark and wood of infected roots and trunks. Fruiting bodies of the fungus, when present, can also aid in diagnosis. The fruiting bodies are honey- colored mushrooms that develop in tight clusters around the bases of infected trees in the fall. They are gilled and have a ring around the stalk beneath the cap.

Disease Cycle: Armillaria root disease infection centers usually begin around dead infected or dying oaks or other dead hosts. Infection of living conifers most commonly occurs through contacts between healthy conifer roots and infected oak roots or rhizomorphs (specialized fungal structures growing from infected roots). Spread may continue from infected to healthy conifers via root contacts. Infection of living conifers is often associated with stress factors such as drought, defoliation, bark beetles, and excess soil moisture.

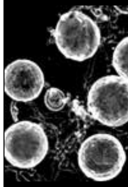
Damage and Importance: *Armillaria* spp may be found in most coniferous and hardwood forest areas, but *A. mellea*, the most widespread and virulent of the four species in California, tends to be most damaging on sites previously inhabited by hardwood forests and is particularly damaging in irrigated orchards and vineyards. The fungus attacks the roots and root crown of trees of all ages, killing the cambium and inner bark and causing a decay of both sapwood and heartwood. In conifers, seedlings and saplings are usually more susceptible than are poles and sawtimber trees. In younger trees, the pathogen advances rapidly through the inner bark to the root collar, where it girdles and kills the tree. In older trees, *Armillaria* spp. often does not kill its host, although it often structurally weakens the roots and predisposes the tree to windthrow. Infected trees often have susceptibility to bark and engraver beetles.

Management Strategies: Do not cut or kill oaks near conifers. If the oaks are young, cut and manage them for sprouts. Older oaks can be pruned to reduce transpiration and competition. Since the disease is more damaging in stressed stands, thin to avoid overcrowding. In orchard or vineyard situations, avoid overwatering in the summer. Conifer stump removal has been recommended in certain situations in the Pacific Northwest, but has not been tested in California.

References

Baumgartner, K. and D.M. Rizzo. 2001. Distribution of *Armillaria* species in California. Mycologia 93:821-830.

Baumgartner, K. and D.M. Rizzo. 2001. Ecology of *Armillaria* spp. in mixed-hardwood forests of California. Plant Disease 85:947-951.



Black Stain Root Disease (*Leptographium (Verticicladiella) wageneri*)

Hosts: Ponderosa and Jeffrey pine, pinyon pine, and Douglas-fir. Lodgepole pine, western hemlock, mountain hemlock, sugar pine bristlecone pine and knobcone pine are also susceptible, but damage is rare.

Distribution in California: Southern Cascades, Klamath and Siskiyou mountains, and northern Sierra Nevada (ponderosa and Jeffrey pines); southern California (singleleaf pinyon pine); throughout the range of Douglas-fir (Douglas-fir)

Characteristics: There are three distinct taxonomic varieties (subspecies) of the black stain root disease pathogen. Each variety has a unique set of hosts, and all are found in California. *Leptographium wageneri* var. *wageneri* is pathogenic to pinyon pine; *L. wageneri* var. *pseudotsugae* causes black stain root disease in Douglas-fir; and *L. wageneri* var. *ponderosum* attacks ponderosa, Jeffrey and lodgepole pine, and occasionally sugar pine and hemlock. Black stain root disease is a vascular wilt disease. It kills trees by blocking their water conducting vessels, and can cause substantial mortality. It does not cause decay of root or stem tissue.

Black stain root disease center in ponderosa pine

Photo: John Kleijunas

Colonization of the root system causes a visible decline in the tree crown. Terminal growth is reduced, needles become shorter and chlorotic, the number of needles produced and retained is reduced ("lion's tail" appearance of branches), and finally the host dies. Disease centers appear as small (usually less than 0.04 ha or 0.1-ac) groups of dead and symptomatic trees. Infection centers can sometimes be much larger, especially in ponderosa pine stands. Typical infection centers have trees in various stages of decline near the perimeter and dead trees in the interior where infection originated. Trees with black stain root disease are frequently predisposed to bark beetle infestation.

Black stain root disease in ponderosa pine

Photo: Pete Angwin

Symptoms and Signs: Black stain root disease is relatively easy to identify in the field. It produces a distinctive dark brown to black sapwood stain in the roots and root crown that sometimes streaks upward into the lower bole. Cross sections of the wood reveal the stain to be in arcs that follow the annual rings. This stain differs from blue stain, which is more bluish, wedge-shaped in cross section, follows the rays, and is associated with beetle galleries throughout the tree. In black stain-infected overstocked pole sized ponderosa or Jeffrey pine stands or understories, a common symptom is numerous haphazardly fallen stems laying in a 'jack-strawed' manner.

Black stain in sapwood

Photo: Don Owen

Disease Cycle: Infection centers may be initiated by root-feeding bark beetles and weevils that carry fungal spores on their bodies. These insects are attracted to wounds, the roots of fresh stumps, and weakened, low-vigor trees, which may account for the common association of the disease with disturbances. Infection of pines appears to be favored by wet, cool environments. Local tree-to-tree spread is via infection of small rootlets, following either root contact or short- distance growth of the fungus through soil. Disease centers can enlarge at a rate of four to twelve feet per year. Although the fungus can remain for long periods in live host tissue, it is relatively nonpersistent and is difficult to isolate from infected wood more than a year after the tree has died. While bark beetles and root feeding weevils are most frequently cited as being the long distance vectors for this disease, the percentage of recovery of the fungus from these insects is usually low, suggesting that there may be many species of vectors, each with a low rate of vectoring.

Damage and Importance: Black stain root disease usually is found in areas where there has been significant site disturbance or substantial amounts of tree injury, especially in stands after precommercial thinning, along roads, skid trails and landings, on sites with drought-stressed, waterlogged, or compacted soils, or where rotary blade brush cutters have been used to clear roadsides. Certain characteristics are related to black stain root disease in ponderosa pine in the central Sierra. Stands are usually densely stocked and consist of either pure or predominantly ponderosa pine. The largest and most rapidly expanding disease centers are often in cool, low-lying sites with high soil moisture levels in the spring.

Black stain root disease and western pine beetle caused-mortality

Photo: Dave Schultz

In recent years, black stain root disease has been detected in many new areas, often causing locally severe damage. Incidence appears to be steadily increasing. While the disease is common in cool, wet, overstocked and disturbed sites, bark beetle-caused mortality of trees that are weakened by *L. wageneri* can likewise be significant during and immediately after periods of drought and other stress.

Crown symptoms of black stain root disease

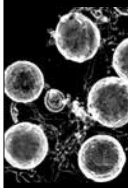
Photo: Don Owen

Ecological Roles: *Leptographium wageneri* creates stand openings, enhances diversity, provides wildlife habitat, and alters forest structure, composition, and succession. Black stain root disease's impacts should be considered from the perspective of how they will influence the ability to attain the desired stocking necessary for meeting management objectives. As with other root diseases, high levels of inoculum in relatively pure stands of susceptible species may preclude achieving adequate stocking in the future. In Douglas fir stands at the lower elevational and latitudinal limits of the host species, this disease was observed driving a species shift towards pines and incense cedar.

Management Strategies: At the present time, there is no effective cure for trees that are already infected, and genetically resistant host genotypes have not yet been identified. Indications from the few long-term field studies that have been conducted suggest that disease impacts may be minimized by maintaining trees in a vigorous condition with adequate spacing while avoiding disturbance and injury, especially during times of peak beetle activity. Partial cutting to attain these objectives can increase or decrease black stain root disease incidence in a stand, depending on: 1) the amount of soil disturbance that occurs, 2) the time of year that the partial cutting is performed, 3) the amount of host-to-host root contact that remains, and 4) the amount of damage inflicted on residual trees. However, a recent study by Otrosina *et.al.* (2007) in ponderosa pine suggests that regardless of how it's carried out (with high disturbance or low, or during the spring or fall), black stain root-disease-caused mortality is far less in thinned stands than in unthinned stands.

Several management actions have been suggested to reduce the establishment of new infections and minimize the effects of the disease where it is already present:

- When establishing new stands in or near areas where black stain has been a management concern, a mix of species should be planted to provide future options for species manipulation.
- When thinning, thin aggressively during each entry, leaving an understocked stand. This will reduce the frequency of harvest entries and associated soil disturbance. Reduced stocking may contribute to disease resilience in a stand because uncrowded trees are more vigorous and less attractive to insect vectors of *L. wageneri* and other bark beetles. Open stands will also have warmer soils that inhibit *L. wageneri* and fewer root contacts between susceptible trees.
- Thin stands as early in the rotation as possible.
- During thinning, favor tree species that are resistant or immune to the locally important variant of *L. wageneri* and remove diseased or weakened trees.
- Whenever possible, leave trees that are not hosts for black stain root disease.
- When host tree species have been removed from an infection center, wait at least twoyears before replacing with host species.
- Harvest in a manner that minimizes soil disturbance and injury to the roots and boles of residual trees. Sites with soils that are prone to compaction by heavy equipment should not be tractor logged. Where timber harvest occurs, high-lead and skyline yarding or helicopter logging is preferred over tractor logging. If tractor logging is the only option, skid trails should be designated to minimize the area that is compacted.. Tree falling should be done to the yarding/skidding lead, and yarding/skidding should be restricted to the dry season when the risk of serious compaction is reduced. New road construction through high risk areas should be avoided. If construction occurs or old-roads must be re-opened, injured trees or those covered by side-cast fill should be removed. Efforts should be made to avoid injuring trees to be retained on site. This should preclude the use of rotary-blade brush cutters on roads adjacent to high risk areas.
- If possible, thin when insect vectors are least active, generally from late June to early September, allowing time for roots to dry out by fall. In areas where summer months are dry and droughty, the thinning period may be extended into late September. Late fall thins are not recommended because stumps may still attract insect vectors the following spring.
- Reintroduce frequent low intensity ground fires into the landscape. This will prevent ingrowth of brush or conifers which can stress host trees and create host-to-host root contacts. Monitor post-harvest black stain root disease activity to evaluate the effectiveness of various levels of thinning.



References

Adams, D.H. and F.W. Cobb, Jr. 1986. Infection of outplanted Douglas-fir seedlings by *Verticicladiella wageneri* (Blackstain Root Disease) when planted around infected Douglas-fir stumps. California Forestry Note No. 98, 12 p.

Hadfield, J.S., Goheen, D.J., Filip, G.M., Schmitt C.L., and Harvey, R.D. 1986. Root diseases in Oregon and Washington conifers. USDA For. Serv., PNW Region, R6-FPM-250-86. 27 p.

Hessburg, P.F., D.J. Goheen and R.V. Bega. 1995. Black stain root disease of conifers. USDA Forest Service, Forest Insect and Disease Leaflet 145. 9 p.

Otrosina, W.J., J.T. Kliejunas, D.R. Cluck, S.S. Sung and C.D. Cook. 2007. Black stain root disease studies on ponderosa pine- parameters and disturbance treatments affecting infection and mortality. Acta. Silv. Lign. Hung., Spec. Edition. p. 247-251

Phytophthora cinnamomi root disease (*Phytophthora cinnamomi*)

Hosts: Most tree species.

Distribution in California:

Madrones killed by *Phytophthora cinnamomi* in Sonoma Co., CA

Photo: Jack Marshall

Characteristics: This root disease is caused by the Oomycete *Phytophthora cinnamomi*, an aggressive pathogen that attacks the fine roots of most woody plants. Infections occasionally spread into the woody roots, collar, and trunk of the tree. Symptoms become apparent on drought-stressed trees in the summer, when wilting and yellowing foliage is seen. Other symptoms include black cankers spreading from the soil line with a cinnamon-colored stain underneath the bark at the canker margin. Infected feeder roots are blackened and collapsed. Infected trees can be found at the bottom of slopes or in waterlogged areas.

Disease Cycle: *Phytophthora cinnamomi* requires moist soils and warm temperatures to survive outside the host. The organism spreads in water by releasing swimming zoospores that attach to roots and infect the host tree. Chlamydospores are also formed, allowing the organism to survive in the soil and dead plant debris until favorable conditions for germination occur. All structures of this pathogen are microscopic and so it is mostly recognized by symptoms. It can spread long distances in potting mix on nursery stock, on soil clinging to tires, equipment, and shoes, and in runoff water.

Damage and Importance: *Phytophthora cinnamomi* is thought to have been introduced to the rest of the world from Southeast Asia and is considered to be one of 100 of the "Worlds Worst Invaders". It has impacts on both forests and agricultural crops.

Management Strategies: Preventing introduction of *P. cinnamomi* into a forest is the best management strategy. Ensure that soil is removed when moving equipment, personnel, or vehicles from an infested area. Improving drainage to prevent waterlogging will also reduce the impact of the disease.

For more information see

Global Invasive Species Database

http://www.issg.org/database/species/ecology.asp?si=143&fr=1&sts=&lang=EN

Port-Orford-Cedar Root Disease (*Phytophthora lateralis)*

Hosts: Port-Orford-cedar (*Chamaecyparis lawsoniana*), Pacific yew (*Taxus brevifolia*)

Distribution in California: Port-Orford-cedar (POC) is found on approximately 35,000 acres in California; primarily on the Six Rivers National Forest and also on the Shasta -Trinity and Klamath National Forests. Eight percent of these acres are currently (2008) infested, mostly in the Smith River drainage.

Characteristics: *Phytophthora lateralis*, the non-native pathogen that causes POC root disease, kills ninety percent of the POC in stands it infests (and more in the larger size classes). The pathogen spreads in several ways: 1) Over long distances via resting spores transported in infested plant material or soil; 2) locally via waterborne spores moving in ditches, streams, or overland flow; or 3) via mycelia growing across root contacts and grafts between infected and uninfected POC.

Sites considered at high risk for *P. lateralis* spread and infection are low-lying wet areas (infested or not) that are located downslope from already infested areas or below likely sites for future introductions, especially roads.

Pacific yew can be infected by *P. lateralis*. Where it has been found infected, Pacific yew was growing in close association with many previously infected POC. Observations and laboratory trials show that Pacific yew is much less susceptible than POC.

Symptoms and Signs: The initial symptom is simultaneous discoloration of the foliage throughout the crown. Discoloration progresses from a slight lightening in color to bronzing and then to browning. Prior to tree death, cinnamon brown discoloration of the inner bark and cambium at the root collar is evident.

Disease Cycle: Zoospores of *P. lateralis* infect fine root tips, causing rootlet decay. The pathogen advances in the inner bark and cambium of the roots to the root collar and slightly up the stem. Resting spores, chlamydospores, develop in the rootlets and are released in the soil as the rootlets deteriorate. Movement of chlamydospore-infested soil by humans or animals helps to spread the pathogen. The chlamydospores remain dormant until the soil is saturated, when they germinate and release zoospores. These zoospores swim and spread in the water and infect new root tips.

Stain from POC root disease and galleries of the bark beetle *Phleosinus sequoiae*

Photo: Don Owen

Damage and Importance: Although POC has a narrow geographic range, it occupies many different environments. The species is found at elevations from sea level to 6,400 feet, in glacial basins, along streams, on terraces, and on mountain side-slopes from lower to upper one-third slope positions. Port-Orford-cedar shows adaptability to a wide range of summer evapotranspiration stress, from very high humidities along the coast to very low summer humidities inland.

POC provides an uncommon ecological function on ultramafic soils and loss of this species can

Port-Orford-cedar mortality due to Port-Orford-cedar root disease

Photo: Pete Angwin

prevent the attainment management objectives. POC on average makes up 38 percent of the overstory on ultramafic upland sites and 50 percent of the overstory on ultramafic riparian sites. Because it is often one of the few, or only, tree species that can tolerate these sites, POC has a key role in maintaining their function through shading and stabilizing soils. POC mortality along streams in ultramafic soils where few other species are available to replace them, will decrease shading and increase temperatures. If stream temperatures are already fish-limiting, this POC mortality will adversely affect fish.

Management Strategies: Overall management objectives for POC are as follows:

1. Maintain POC on uninfested sites and sites where the risk for infection is low.
2. Reduce the spread of the pathogen and intensification of root disease in high- risk areas and retain the ecological function of POC to the extent practicable.
3. Reestablish POC in plant communities where their numbers or ecosystem functions have been reduced. Where appropriate, replant with disease- resistant stock.
4. Reduce the likelihood of root disease becoming established in disease-free watersheds.

Where the disease is absent, preventing the establishment of new infestations is the most prudent and effective management practice available. An integrated approach to deal with the spread of *P. lateralis* includes prevention, restoration, detection, evaluation, suppression, and monitoring. Management goals are directed toward maintaining POC and reducing root disease losses.

General Standards and Guidelines for the management of POC in California are contained within the individual Land and Resource Management Plans (LRMPs) for the Klamath, Shasta-Trinity, and Six Rivers National Forests. These documents describe many of the current programmatic and project-specific best management practices that may be used to reduce the spread of *P. lateralis* and maintain POC as an ecologically and economically significant species on National Forest lands in California.

A full list of POC management strategies and practices can be found in MANAGING FOR HEALTHY PORT-ORFORD-CEDAR IN THE PACIFIC SOUTHWEST REGION (http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5332563.pdf)..

Additional information on POC and POC root disease management can be found in the 2003 POC Rangewide Assessment: (http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5316517.pdf)

Reference

Betlejewski, F., D.J. Goheen, P.A. Angwin and R. A. Sniezko. 2011. Port-Orford-root disease. USDA Forest Service, Forest Insect and Disease Leaflet 131. 12 p

Sudden Oak Death

Sudden Oak Death *(Phytophthora ramorum)*

Hosts: *P. ramorum* is also a bark/cambium pathogen causing necrotic cankers and mortality of tanoak *(Lithocarpus densiflorus)* and four (of California's 28) true oak species: coast live oak *(Quercus agrifolia),* California black oak, *(Quercus kellogii),* Shreve oak *(Quercus parvula,* var. *shreveii)* and Canyon live oak *(Quercus chrysolepis).* The pathogen has also been isolated from the foliage of over 128 tree and shrub species and causes leaf spots and/or twig dieback on California bay laurel *(Umbellularia californica),* rhododendron, big leaf maple *(Acer macrophyllum),* madrone *(Arbutus menzeisii),* huckleberry *(Vaccinium ovatum),* California buckeye *(Aesculus californica),* manzanita *(Arctostaphylos manzanita),* toyon *(Heteromeles arbutifolia),* California honeysuckle *(Lonicera hispidula),* California coffeeberry *(Rhamnus californica)* poison oak *(Rhus diversiloba)* and Cascara *(Rhamnus purshiana). P. ramorum* has also been identified associated with redwood *(Sequoia sempervirens)* sprouts and needles and Douglas-fir *(Pseudotsuga menziesii)* twigs and needles. Other tree hosts in California and Oregon include white fir *(Abies concolor),* red fir *(A. magnifica)*, grand fir *(A. grandis),* Pacific Yew *(Taxus brevifolia),* canyon live oak *(Q. chrysolepis)* and California nutmeg *(Torreya californica).*

Distribution in California: Sudden oak death is presently limited to 15 counties largely along the central and north coast of California. These include Monterey, Santa Cruz, Santa Clara, San Mateo, Contra Costa, Alameda, Solano, San Francisco, Marin, Napa, Sonoma, Lake, Napa, Mendocino, Trinity and Humboldt Counties and Curry County, Oregon. Although increased inspection controls mandated by the California Department of Food and Agriculture have resulted in a significant drop in the number of nurseries producing infected stock, it continues to occasionally appear in some California nurseries.

Distribution of Sudden Oak Death as of December 2014

Map by Brendan Twieg

Characteristics: *Phytophthora ramorum* is an exotic organism in California, Oregon and Europe. It was first identified in the 1990's killing oaks and tanoaks along the central coast of California and has been spreading north and south since then and has had an ever expanding host range including hardwoods, conifers, and understory shrubs, ferns and herbaceous plants. Currently *Phytophthora ramorum* is a quarantined pest in California, resulting in restrictions on the movement of host material out of the zone of infestation, especially to other states and countries.

Infections by *P. ramorum* occur on leaves, branches, shoots, and stems. Leaf spotting, needle dieback, tip dieback, and bleeding stem lesions can be found. Symptoms vary significantly by host.

P. ramorum zone lines on coast live oak

Photo: Joe O'Brien

Bleeding from *P. ramorum* canker on coast live oak

Photo: Joe O'Brien

P. ramorum symptoms on California bay laurel

Photo: Rob Gross

Bleeding Cankers: The bark canker hosts are tanoaks, coast live oak, Shreve's oak, canyon live oak, and black oak. Only larger oaks (>4 in. DBH) are attacked and attack occurs solely above the root collar. All ages and sizes of tanoak are susceptible to infection. Cankers on the trunk of tanoak trees usually lead to death but sometimes there is remission when the cankers are on the true oak species. Bleeding on oaks and tanoaks can be washed off by rain or can dry up and be less apparent over time so a lack of apparent bleeding may not mean that a tree is uninfected.

Additionally, diseased oak and tanoak trees are often attacked by other organisms once they are weakened by *P. ramorum.* These secondary invaders include such organisms as *Hypoxylon thourasianum* (a fungus that decays sapwood) and ambrosia beetles.

Tip Dieback: Tip dieback of branches can occur on a number of hosts. Tanoaks, rhododendron and Douglas-fir often have infections causing the tips of shoots to die.

Leaf Spots and Needle Dieback: In foliar and twig hosts, symptoms can range from leaf spots to minor twig dieback, but these hosts rarely die from the infection. The majority of hosts only have leaf spots or some needle dieback. For example on bay laurel, *Phytophthora ramorum* causes leaf spots, usually brown leaf tips surrounded by a halo of yellow. Lesions are typically found where water collects on the leaf. Although most leaf spot and needle dieback hosts rarely suffer major damage, they act as a source of inoculum for infection of the oaks and spread of the disease. Tanoak is a leaf spot host and also suffers from shoot dieback and fatal bleeding cankers.

Accurate disease diagnosis can be difficult because all the symptoms types caused by *Phytophthora ramorum* are very similar to those caused by other fungi, insects, or adverse environmental conditions. The only way to confirm a *P. ramorum* or sudden oak death infection is to have a sample of affected plant tissue analyzed in an approved laboratory.

Disease Cycle: *P. ramorum* thrives in cool, wet climates. In California, coastal evergreen forests and tanoak/redwood forests within the fog belt are the primary habitat. Research in California forests has shown that the greatest predictor of *P. ramorum* is the presence of California bay laurel (*Umbellularia californica*) because their leaf tips can produce sporangia abundantly. Nurseries outside of these cool, moist areas often artificially create microclimates which mimic the preferred environment of *P. ramorum*.

Tanoaks and oaks that get the basal cankers are usually infected for several years prior to the visual occurrence of symptoms and the death of the trees.

Damage and Importance: It is estimated that, to date (2015), at least 3 million tanoak and two hundred thousand coast live oak have been killed due to sudden oak death. Changes in species composition in infested forests and loss of food sources (acorns) for wildlife are assumed. Also, for at least a period of 1 to 5 years after an epidemic moves through a forest stand, there can be

Tanoak mortality caused by *P. ramorum* in western Marin County

Photo: Jeff Mai

a significant fuels buildup which could lead to more intense wildfires. Tanoaks have shown little resistance to the disease and may be completely eliminated from severely impacted areas. However, there is much more variation in resistance among the California live oaks.

Management Strategy: Survey and monitoring activities occur throughout the current range of the pathogen, particularly at the geographical fringes of where the disease is known to be present. A technique called streambaiting is exceptionally useful for determining if a watershed contains any infected trees and is used to get an initial read on whether that watershed is infested with the pathogen. However, because this technique only indicates that the pathogen is somewhere upstream from the bait, it is not particularly useful in identifying the exact stand in a watershed where the tanoak or oak are being affected. Followup aerial surveys are often used to pinpoint these infested stands, and when 10 or more dead trees are present, these infestations can usually be seen by a skilled aerial surveyor. Following aerial detection, field crews are sent to verify the presence of the disease and determine its distribution. Symptomatic leaves are collected and cultured in a laboratory on selective media to confirm the presence of *P. ramorum*. And to distinguish it from other *Phytophthoras* and fungi that can produce similar symptoms

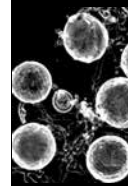
Once the infected area is delimited, control and/or containment measures can be considered. In some parts of California (and almost always in Oregon), eradication treatments consist of cutting and burning host material in disease pockets and within a 300 to 400 meter buffer zone surrounding these pockets. However, the pathogen is fairly elusive and can sometimes show up later outside on the containment zones. For this reason, continued monitoring and eradication treatments may be needed.

For individual, high-value trees, the California Department of Pesticide Regulation has approved a special registration for Agri-Fos. Application of Agri-Fos is currently the only treatment approved by the State for use against *Phytophthora ramorum* on oaks and tanoaks. It is important to note that this compound only prevents uninfected trees from becoming infected- it does not eradicate the pathogen from diseased hosts, and therefore cannot be considered as a cure for individual trees. However, because it can prevent individual trees from becoming infected, it can also be used to slow disease spread to uninfested parts of stands where the pathogen has just been introduced.

Phytophthora ramorum is a federally quarantined pest. Movement of host materials outside the state and to non-infested counties in California is restricted. Nursery stock must be inspected and certified disease-free. The California Depatment of Food and Agriculture performs this service. Infested nurseries may be sanitized and recertified.

References

Additional information on Sudden Oak Death is at the Sudden Oak Death Task Force Web site: http://www.suddenoakdeath.org



Rusts

Rust diseases are caused by a specialized group of fungi known as obligate parasites. This means that they can develop only on living host tissues. Rusts pass through up to five different spore stages in their life cycles. Many produce these spores on two unrelated hosts and must alternate from one to the other to complete their life cycles. Others parasitize only a single host.

Rust fungi can infect foliage, twigs, branches, or stems, and develop within the host to form leaf spots, swellings, systemic infections, or cankers. Severe infections may reduce wood quality, retard growth, and kill individual trees. The most damaging rust, white pine blister rust, was introduced to the west coast of North America in 1910 on eastern white pine seedlings grown in France and continues to pose a serious threat to the regeneration and management of sugar pine in California. Because of its impacts on ecosystem diversity, it is also a major concern in high elevation western white pine, whitebark pine, foxtail pine, bristlecone pine, and limber pine. Western gall rust can also cause a great deal of damage. Other native rusts are of lesser importance.

Rusts of Conifers in California

Table 6. Rusts of Conifers in California

Disease	Pathogen	Principal Conifer Hosts	Alternate Hosts
White Pine Blister Rust	*Cronartium ribicola*	Sugar pine, other 5 needle pines	Predominantly *Ribes* spp. gooseberries, currants; some *Castilleja* spp. (paintbrush) and *Pedicularis* spp. (louseworts)
Pinyon Rust	*Cronartium occidentale*	Pinyon pines	*Ribes* spp.
Stalactiform Rust	*Peridermium stalactiforme*	Lodgepole, Jeffrey, ponderosa, and coulter pines	*Castilleja* spp. (paintbrush) *Pedicularis* spp. (louseworts)
Filamentosum Rust (limb rust)	*Cronartium arizonicum* (*Peridermium filamentosum*)	Jeffrey and ponderosa pines	*Castilleja* spp.
Western Gall Rust	*Endocronartium harknessii* (*Peridermium harknessii*)	Monterey, Jeffrey, lodgepole, and ponderosa pine	None
Comandra Blister Rust	*Cronartium comandrae*	Lodgepole and ponderosa pines	*Comandra* spp. (bastard toadflax)
Incense-cedar Rust	*Gymnosporangium libocedri*	Incense-cedar	Amelanchier (serviceberry, juneberry), *Crataegus* (hawthorn)
Yellow witches' broom of fir (fir broom rust)	*Melampsorella caryophyllacearum*	White and red firs	Chickweeds aka sandworts, starworts (*Stellaria, Cerastium*)

*All species listed in the table, except for *Gymnosporangium libocedri* and *Peridermium harknessii*, produce pycnia and aecia on the conifer host, and uredia and telia on the alternate, herbaceous host. The pine rusts cause branch flagging, branch swellings, and cankers on pines. Incense-cedar rust and yellow witches' broom of fir cause broom formation – dense, compact growths of many short, contorted branches.

White Pine Blister Rust (*Cronartium ribicola)*

Hosts: Sugar pine, western white pine, other white pines; currants, and gooseberries (Ribes spp.); some paintbrushes and louseworts (*Castilleja* and *Pedicularis* spp.)

Distribution in California: Throughout the range of the pine hosts, except the southern extreme of the sugar pine range.

Rust sporulating on the bole of an infected tree

Photo: Danny Cluck

Characteristics: Symptoms of white pine blister rust include needle spots, cankers, branch "flagging" (yellowing and red needles beyond the infection), abundant sap flow from cankers, and production of "stress cones". Needle infections appear as colored spots on the needles. These spots can be yellow to orange, or even red. In the field, needle spots caused by blister rust can easily be confused with weather spots. Thus, field evaluation of needle infections is extremely difficult.

Blister rust cankers can be identified by their color, shape, and texture. The early incipient canker is an orange circular swelling at the base of the needle fascicle. As the canker ages, the infection spreads to adjacent tissues. The middle of the canker is the oldest portion and is characterized by a cracked and roughened surface. The living tissue around the canker can be swollen, or even sunken. The canker is fusiform in shape and causes girdling and death of the branch or main stem when it grows around the stem. As branches die, yellow and red needles (called "flags") become evident in the crown. This flagging should not be confused with the natural dieback of lower branches, which lack the roughened cankers.

The most readily observable sign of blister rust in the field is the aeciospores. These are bright orange in color and are produced in fruiting bodies (aecia), which are formed within the cracks of the cankers. Fresh aeciospores are typically visible during the spring months.

Disease Cycle: *Cronartium ribicola* passes through five different spore stages in its life cycle. On the pine host, two spore types (pycniospores and aeciospores) are produced. On the alternate host (the *Ribes*, and less frequently, louseworts and paintbrush) three spore types (urediniospores, teliospores, and basidiospores) develop in the same growing season.

Basidiospores infect the pine by germ tubes that grow through the stomata (air exchange pores) of the needles. Fungal hyphae colonize the needles, so infection sites can be recognized as bright yellow or reddish-colored spots in 6 to 10 weeks. The fungus grows down the needle to infect the stem . Stem infections first become visible a year or more after initial needle infections. Early stem infection is typically seen as a yellowish orange discoloration at the base of the needle fascicle. Cankers develop later, as further fungal growth and spore production disrupts the living tissues in the bark.

Pycniospores are produced on infected stems within 2 to 3 years from initial infection. The pycnial drops contain foul-smelling, sweet-tasting, nectar-like substances that attract flies and other insects. These insects move from canker to canker, carrying pycniospores that fertilize other infections. This step is necessary for the development of aeciospores.

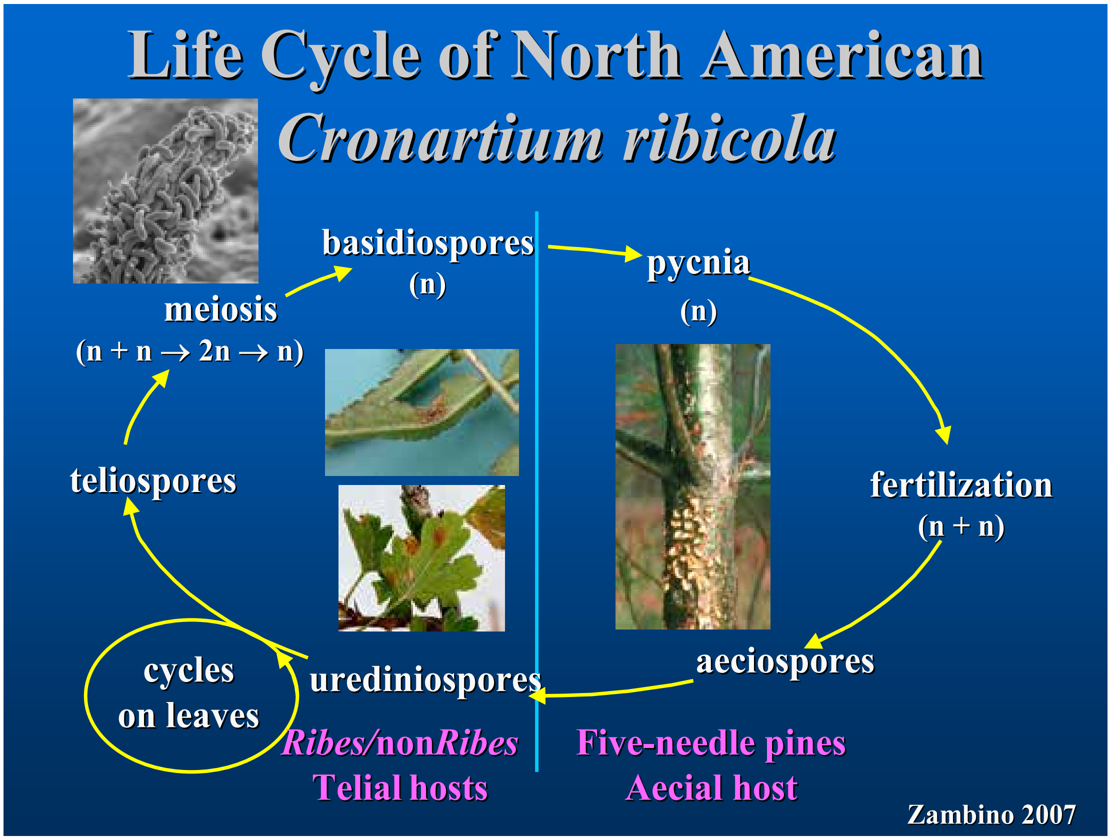


Figure 5. Life cycle of North American *Cronartium ribicola*

Aeciospores are produced the next year, from wherever pycnia were fertilized. These spores can be wind disseminated for miles. They germinate on the under surface of alternate host leaves when temperature and moisture conditions are right. The germ tubes of these spores enter through stomata and infect the leaves. Later, orange pustules about the size of a pin head appear on the undersurface of the ribes leaves. These are the urediniospores. They are capable of starting new infections on ribes leaves, thus intensifying the infection. With the onset of cool, moist weather the leaf infections shift from producing uredinospores to making minute hair-like columns of cells called teliospores. These spores germinate and produce delicate basidiospores which lose viability easily and are not normally dispersed very long distances. The basidiospores are carried back to the pines, thus completing the life cycle.

Damage and Importance: White pine blister rust has been devastating to sugar pine since the disease entered northern California around 1930. Although the spread of blister rust in the Sierras has been slow and erratic, infections have been reported over the entire range of the species, except a few isolated populations. Because sugar pine is one of the most valuable conifer trees species in the mixed conifer stands of California, much emphasis has been placed on the management of blister rust in order to maintain sugar pine as a significant component of the mixed conifer type. In addition, because of the ecological importance of high elevation five needle pines such as western white pine, whitebark pine, foxtail pine, bristlecone pine, and limber pine, white pine blister rust is a major concern.

Uredia stage on alternate host *Ribes*.

Photo: Robert Anderson

Management Strategies:

Genetic Strategies– Some sugar pines are resistant to blister rust infection. By selecting and studying apparently rust-resistant trees, scientists have identified a dominant major gene for

Summary of White Pine Blister Rust Spore Stages

Table 7. Summary of White Pine Blister Rust Spore Stages

Stage/Structure/Spore Type	Host	Spore Characteristics
0 – pycnia – pycniospores	5 – needle pines	In sweet, amber-colored fluid that exudes from young cankers; sexual function (not infective)
I – aecia – aeciospores	5 – needle pines	Bright yellow-orange, powdery spores produced in cankers; cannot re-infect pine but are blown long distances where they may infect alternate host; remain viable several months under favorable conditions
II – uredinia – urediniospores	Currants and gooseberries, some paintbrushes and louseworts	Orange powder on bottom leaf surfaces; spores re-infect leaves to form more uredinia as long as conditions are favorable, up to 7 generations per season
IIIa – telia – teliospores	Currants and gooseberries, some paintbrushes and louseworts	“Hairy” protrusions on undersides of leaves; from established urediniosori or new infections under cool night conditions; spores are not dispersed but germinate in place in telial columns during cool, wet conditions
IIIb – basidium – basidiospores – germ tube of teliospore	Currants and gooseberries	Tiny thin-walled spores subject to desiccation; water-saturated air and temperatures below 69 degrees F promote heavy infection of pine needles

White pine blister rust causes orange or yellow discoloration of thin bark of young trees

Photo: US Forest Service

resistance in sugar pine. The Tree Improvement Program within the Pacific Southwest Region of the Forest Service has adopted a screening program to identify parent trees with the major gene resistance (MGR). Approximately 800 parent trees are screened annually for resistance. Fifty percent of the seeds from resistant trees will produce seedlings with major gene resistance. Seed of resistant trees is identified to seed zone and elevation and kept in storage at the Placerville Nursery in Camino, CA, for production of resistant seedlings for reforestation.

Other forms of resistance, collectively known as “slow rusting,” are also being investigated. The identification of such additional mechanisms will provide a wider genetic base for resistance, which can then be incorporated into planting stock. The planting of resistant stock is the only practical means of control in areas highly favorable to the disease and where seed trees are rare; however, in some areas and pine species, nearly 10% of trees are resistant. This, and a mixture of low and high hazard areas across landscapes, allows some management for regeneration from naturally resistant stock. Similar investigations into the genetic resistance of several species of high elevation five needle pines are also being initiated.

Cultural Strategies – Cultural control is feasible where rust hazard is low, and can be used to supplement resistance. Since rust fungi can survive only on living hosts, removal of trees or branches will successfully eliminate the pathogen from an individual tree or branch. During precommercial thinning, infected trees may be cut. During commercial thinning, infected trees should be removed only if cankers on or near the stem threaten to kill the tree. Trees with single, slow-growing cankers at the base of the tree should not be cut, as these may have high levels of slow-rusting resistance.

Past investigations suggest that pruning may be a feasible means of limiting the effect of white pine blister rust in some areas. Growth of the fungus through conifer tissue is slow, generally one to two inches per year; thus, lightly infected trees may be pruned free of branch infections if the rust cankers are four to six inches or more from the stem. Many infected trees between 2 and 8 inches in diameter can be pruned free of cankers if 1) pruned to half the tree height (or to 18 feet for trees taller than 36 feet), or 2) only the lower third of the crown is pruned and infected branches from the remaining lower whorls are cut. The pruning of selected lightly infected sugar pines during precommercial thinning may allow the stand to reach merchantable size, and may be less expensive than regenerating the stand. Pruning is biologically feasible in areas where levels of infection are not excessive, but the costs of pruning may be restrictive in all cases except stands of very high value. Pruning during fuels-reduction treatment can help achieve multiple management objectives.

Extensive efforts were at one time directed toward control of blister rust through the eradication of Ribes spp. This approach proved ineffective, due to the high cost and difficulty of completely eliminating the plants. More importantly, Ribes regenerate rapidly from seed when soil is disturbed mechanically or after fire, and some Ribes seed has been shown to remain dormant but viable for hundreds of years. Also, it has recently been found that non-Ribes alternate hosts can spread infection in some locations, particularly the sub-alpine zone. Thus, Ribes eradication is no longer considered a viable means for controlling white pine blister rust.

References

Benedict, W.V. 1981. History of White Pine Blister Rust Control: A Personal Account. USDA Forest Service Publication FS-355. 47 pp.

Byler and Parmeter. 1979. An Evaluation of White Pine Blister Rust in the Sierra Nevada. FIDM Report No. 79-3

McDonald, G.I.; Richardson, B.A.; Zambino, P.J.; Klopfenstein, N.B.; Kim, M.S. 2006. Pedicularis and Castilleja are natural hosts of Cronartium ribicola in North America: A first report. Forest Pathology 36: 73-82.

McDonald, G.; Zambino, P.; Sniezko, R. 2004. Breeding rust-resistant five-needle pines in the western United States: Lessons from the past and a look to the future. Pp. 28-50 In: Sniezko, R.A.; Samman, S.; Schlarbaum, S.E.; Kriebel, H.B., eds. Breeding and genetic resources of five-needle pines: growth adaptability, and pest resistance. IUFRO Working Party 2.02.15: proceedings; 2001 July 24-25; Medford, OR, USA. Fort Collins, CO: U.S.D.A. Forest Service, Rocky Mountain Research Station. RMRS-P-32.

Zambino, P.J.; Richardson, B.A.; McDonald, G.I. 2007. First report of the white pine blister rust fungus, Cronartium ribicola, on Pedicularis bracteosa. Plant Disease. 91: 467. doi:10.1094/PDIS-91-4-0467A

Western Gall Rust (*Endocronartium harknessii (Peridermium harknessii*))

Hosts: Very common on lodgepole and Monterey pine; also occurs on many other pine species, especially ponderosa, Jeffrey and knobcone pine, rare on western white pine; no alternate hosts.

Distribution in California: Statewide

Characteristics: This fungus forms round or pear-shaped galls on the main stem or branches, which emit orange spores. Galls on main stems may grow for years becoming very large or may partially girdle the stem and die, forming large cankers. Conspicuous yellow-orange spore pustules (aecia) are produced in cracks on galls in spring and early summer.

Western gall rust sporulating on branch

Photo: Jim Byler

Disease Cycle: Western gall rust is capable of infecting pines directly without going to an alternate host. Spores are produced on galls in the late spring to early summer, are disseminated by wind, and infect the green tissue of new shoots. Small galls appear a few months after infection but do not produce spores until the following year. Galls grow each year and produce spores every spring until the gall tissue dies as a result of host death or is inactivated by parasites

Damage and Importance: Endocronartium harknessii is widespread throughout the Pacifi states. It is most commonly found in riparian areas, around meadows, and in other low-lying areas where moist air collects. It causes branch flagging, growth loss, stem malformation, and mortality of young trees. Some brooming and proliferation of lateral branches may result from infection. Branch dieback may be locally severe. Damage is not usually significant on older trees if only branches are infected. Damage becomes more important with main stem galls or with large numbers of branch infections on young trees. Trees with stem cankers are prone to breakage.

Ecological Roles: Gall rust is a winnower of pines growing in wet areas and in very dense stands. It causes mortality and breakage of highly susceptible trees and favors more resistant ones.

Management Strategies: Avoid planting susceptible hosts in areas of heavy infection. Discriminate against infected trees, especially those with stem cankers, during stand entries.

References

Scharpf, R. F., tech coord. 1993. Diseases of Pacific Coast Conifers. USDA For. Serv. Ag. Hndbk. 521. 199 p.32, 58

Peterson, R. W. 1960. Western gall rust on hard pines. USDA For. Serv., For. Ins. & Dis. Leaflet 50, 8 p.

Tree Decays

Characteristics: Stem decays are widely distributed and are caused by many species of fungi that attack and decompose woody cell walls. Some of these fungi decay only the heartwood of living trees while others decay the heartwood and/or sapwood of dead trees. As a rule, heartrot fungi do not penetrate sound trees but require an opening into the heartwood through which to invade. Any opening into the heartwood or exposure of dead sapwood next to heartwood is a potential site for decay fungi to become established. Some decay fungi enter the heartwood via natural openings (e.g. knots, branch stubs, dead branches or branchlets). Others require a wound to enter. Wounds caused by fire, weather, animals, or human activities are common points of entry for decay fungi. There are also decay fungi that enter through roots and kill the root wood before entering the heartwood.

Several systems have been devised to identify and classify decay fungi. The three most widely used are based on the type of decay, the characteristics of the fungal fruiting body (the sporophore or conk), or the part of the tree affected.

In the first scheme, two general types of decays are recognized; brown rots and white rots. Brown rots develop as a result of the selective digestion of carbohydrates (primarily cellulose) by the fungi, leaving behind the brownish lignin components of the wood. Brown rotted wood is usually dry and fragile; it tends to crumble readily or break into cubes. Most brown rots form solid columns of decay, while some appear in pockets. White rots are produced by fungi that digest both the carbohydrate and lignin components of the wood. They may form in pockets or be stringy in nature.

The second system used to identify decay fungi is based on the characteristics of their fruiting bodies. These are often the most reliable indicators of decay in trees, and one of the easiest means of positively identifying the causal agent in the field. These spore-producing bodies vary in form from fleshy mushrooms to woody brackets. Color, texture, and the nature of the spore-producing surface are some of the characteristics used to identify species. Some decay fungi fruit annually, others are perennial. Other indicators of decay include punk knots (decayed branch stubs filled with fungal material which are considered to be places where conks were or where they will develop), swollen knots (protrusions of bark and wood around a branch stub commonly found on Douglas-fir infected with *Phellinus pini*, and evidence of wounding.

The third system separates the heart rots based on the portion of the host that is colonized by the fungi. Decays are separated into top rots, trunk rots or root and butt rots.

Decay, especially in live, standing trees, may be difficult to detect. Some incipient decays cause distinct color changes in the wood (visible if exposed), but others are not obvious or are virtually invisible. If conks are present, they are usually good indicators of decay; however, small (but viable) conks may escape casual inspection. Annual conks may not be apparent at all if a tree is examined at the wrong time of year. Thus, wounds and broken tops or branches often serve as better indicators of hidden decay.

Disease Cycle: The fungi that decay trees may gain entrance through a variety of openings in the bark, including wounds caused by fire, logging, frost, animals, insects, and sunscald; broken tops; branch stubs; small twigs; root infections; and parent stumps (sprouting hardwoods). The location of a wound on a tree may influence which decay organisms become involved in the decay process. Initiation of decay occurs when a spore lands on suitable exposed wood, germinates, and invades the woody tissue. A succession of microorganisms (including bacteria and non-decay fungi) invades the wood following initial infection. Following invasion, a variety of interactions occur among numerous microorganisms and the tree determining the amount and rate of decay.

A concept developed to explain the response of a tree to decay is CODIT (Compartmentalization of Decay in Trees). The system is based on the premise that a tree is a highly compartmented plant and that following wounding, the effects are compartmentalized. Each compartment of a tree has its own set of “walls”. Wall 1 forms the top and bottom of the compartment after wounding when the tracheids or vessels plug up. Wall 2 is the inner wall and is continuous around the growth ring. Wall 3, analogous to side walls, is defined by the ray cells and is discontinuous, both vertically and inward. Wall 4 is formed tangentially and longitudinally by the cambium after wounding and is complete around the growth ring.

Compartmentalization begins when the tree produces chemicals in response to wounding. A succession of microorganisms may then invade and surmount some of the weaker walls and interact with the tree. The strongest wall is wall 4, which usually confines the microorganisms and defect to the wood present at the time of wounding.

Damage and Importance: Tree decay is an important ecological process. As stands mature, decay organisms cause tree failure and breakage, creating canopy gaps. Decay fungi break down wood into organic soil components. These organic components increase soil moisture holding capacity and nutrient availability. Decay is vital to the production of habitat for many wildlife species. Wood softened by decay fungi is preferentially excavated by primary cavity nesting species. These cavities, as well as broken tops and hollow trees and logs created by decay are used by many other wildlife species.

Decays also cause loss in economic value. Breakage and windthrow reduce stocking. Decay of sound wood renders timber unmerchantable and reduces wood quality. Decays are responsible for the loss of millions of board feet of timber each year in North America. These losses occur most frequently in old growth forests, but second-growth stands are seriously affected in some cases.

In general, decay is most prevalent in older, larger trees, due at least in part to the accumulation of wounds and the increase in the proportion of heartwood over time. Heartrot fungi that become abundant in old forests may be important as disturbance agents that initiate and sustain small canopy gaps. They are especially important in areas where large-scale disturbances such as windstorms or fires are infrequent. Breakage associated with heartrots may be one of the main means by which large trees are brought down. Small gaps are created when boles decayed by heartrot fungi break or when trees fail due to decayed roots. Often, when the trees fall, they strike and wound nearby trees. These wounded trees then become susceptible to infection by decay fungi, perpetuating the cycle of rot, breakage, and wounding. The result is a series of small shifting, gaps. In these gaps, regeneration of shade tolerant tree species can occur. When enough light reaches the forest floor, shrubby and herbaceous vegetation grows. The structural variability of the forest is increased by the presence of down wood, regeneration, and understory vegetation.

Habitat created by decay of the heartwood of living trees differs from the habitat created when sound trees die and are decayed from the outside in. Living trees that contain dead, decayed wood can function as wildlife habitat, although the portion of the tree that is useful to wildlife may be smaller than would be the case in a snag of the same size. Live trees with decay generally stand longer than snags. The sapwood of live trees is resistant to decay, even when the heartwood is extensively decayed. Thus, the sapwood remains intact for a long time, forming a protective shell around the decayed heartwood and any nest sites excavated in it.

Hollow trees (and hollow logs that result when hollow trees fall) are formed only by the activity of heartrot fungi in living trees. Hollows occur in the advanced stages of decay when the cylinder of decayed heartwood detaches from the sapwood and slumps down. They are especially common in grand and white fir, western larch and western red cedar. Large-diameter trees, greater than 50 centimeters (20 inches) in diameter at breast height,form hollow chambers (cavities) that are the most useful to wildlife. Hollow trees and/or hollow logs are used by many animal species including black bears, pileated woodpeckers, martens, flying squirrels, northern flickers and Vaux’s swifts.

Decayed wood added to the forest floor by trees that fail contributes to the physical structure and nutrient composition of the soil. It provides food and microhabitats for a myriad of decomposer organisms that form the basis of the food chain in western forests.

Management Strategies: The trade-off between wood production and development and maintenance of decayed wood for ecological functions and wildlife habitat needs must be balanced through thoughtful planning. The percentage of decay that is acceptable will depend upon the specific management objectives. In many areas, harvesting of older stands and targeting of injured and decayed trees for removal has resulted in extensive areas of young stands that lack decayed trees. In other areas, especially in the true fir zone, repeated partial cutting has resulted in stands with very high proportions of decay in the residual trees.

Once they are injured, trees cannot be protected from infection by decay fungi. To reduce injury to residual trees during harvest, managers can limit the number of entries and the operating season, and specify the size and type of equipment, and the falling and skidding practices. Other options are to use short rotations or to selectively remove injured trees during intermediate entries before extensive decay develops. When trees are pruned, proper techniques are essential to avoid creating entry points for heartrot fungi. After harvesting or pruning, slash should be piled away from residual trees to protect them from fire and heat.

In areas where prior management has created extensive, uniformly young stands with insufficient damage or decay to meet the needs of wildlife, it may be desirable to intentionally increase the level of decay. This can be accomplished by intentionally wounding trees or by inoculating selected trees with decay fungi. Where there are older trees that can be retained, correctly identifying and protecting those that are already infected can reduce or eliminate the need to artificially initiate decay.

In developed recreation areas, trees that are affected by stem decays may become unstable and hazardous to visitors. It is important to check trees in these areas periodically for indicators of decay. If such indicators are found, the probability of failure and the presence of potential targets will dictate what treatment is appropriate to reduce or eliminate the hazard. In some cases, creative treatments such as topping, leaving high stumps, and falling but not removing hollow stems may alleviate the hazard while maintaining desirable wildlife habitat.

References

Aho, P.E., Fiddler, G., and Filip, G.M. 1989. Decay losses associated with wounds in commercially thinned true fir stands in northern California. USDA Forest Service, Research Paper PNW-RP-403. 8 p.

Aho, P.E., Fiddler, G., and Srago, M. 1983. Logging damage in thinned, young-growth true fir stands in California and recommendations for prevention. USDA Forest Service, Research Paper PNW-304. 8 p.

Bull, E.L., Parks, C.G., and Torgesen, T.R. 1997. Trees and logs important to wildlife in the interior Columbia River Basin. USDA-Forest Service, PNW-GTR-391. 55 p.

Hennon, P.E. 1995. Are heart rot fungi major factors of disturbances in gap-dynamic forests? Northwest Science, vol. 69 (4): 284-293.

Maser, C. and Trappe, J.M. (technical editors). 1984. The seen and unseen world of the fallen tree. USDA-Forest Service, PNW-GTR-164. 56 p

Table 8. Common Wood Decays of California

Common Wood Decays of California

Common Name	Cause	Hosts	Part Of Tree	Field Id	Decay	Conk	Cull
Red Ring Rot	*Phellinus pini* and *Phellinus cancriformans*	Douglas-fir; true firs; ponderosa, Jeffrey and sugar pines, hemlocks, spruces, western red cedar and rarely incense cedar	Heartwood	Conks, punk knots, swollen knots	White pocket rot, spindle shaped pockets, firm wood in between	Perennial; top: dark brown to black, concentrically furrowed, margin often scalloped; bottom: brown irregular pores	Conk <3" wide: 4 ft. above and below conk; conk 3-6" wide: 8 ft. above and below conk; conk >6" wide: 16 ft. above and below conk; total cull if 2 conks separated by more than ½ tree height
Rust Red Stringy Rot	*Echinodontium tinctorium*	True firs, hemlocks, rarely Douglas-fir and Engelmann spruce	Heartwood	Conks, rusty knots, over-mature timber	White rot, appears orange-red, stringy	Perennial, under limbs; top: black, rough, cracked; bottom: toothed, gray; interior: bright brick red	16 ft. above and below conk, total cull if 2 conks separated by more than ½ tree height
Dry Pocket Rot ("Pecky Rot")	*Oligoporus amarus*	Incense-cedar, rarely in true fir	Heartwood, usually lower bole	Conks, "shot hole" cups, trees >210 years	Brown cubical pocket rot; large pockets filled with decay; sound wood between	Annual, rare; top: tan when fresh, turning black; bottom: bright yellow; insects quickly destroy conks	10-50 ft. above and below conks; not a predictable indicator
Red-Brown Root & Butt Rot (Schweinitzii Root & Butt Rot)	*Phaeolus schweinitzii*	Most conifers, esp. Douglas-fir, pines	Heartwood, roots, and butt log	Conks, basal wounds, soundings, over-maturity	Brown cubical, yellow-brown to dark red brown, irregular cubes. Mats thin if present	Annual, not persistent, from roots or butts; upper: velvety, brown-green margin; lower: yellow-green when fresh; conk fades to dark brown	Cull butt log if conk on or near tree

Common Wood Decays of California (Continued)

Common Name	Cause	Hosts	Part Of Tree	Field Id	Decay	Conk	Cull
Brown Trunk Rot	*Fomitopsis officinalis*	Ponderosa, Jeffrey, lodgepole, western white, and sugar pines; Douglas-fir, spruces, hemlocks and rarely true fir	Heartwood, upper portions of bole	Conks	Brown cubical, dark reddish, thick bitter mycelial felts in cracks	Perennial, large chalky to yellow, high in trees, bitter tasting, rare	Conk indicates total cull. If fungus is in stand, "high risk" trees have broken tops, branches, and wounds.
Brown Cubical Rot	*Laetiporus sulphureus*	Mainly true firs, esp. red fir; Douglas-fir, hemlock, pines and spruce; also oaks, maple, birch and willow	Heartwood, roots, and butt log	Conks, wounds, examination of nearby stumps, over-maturity	Identical to brown trunk rot, but mats are not bitter	Annual, shelving, overlapping; upper: bright flame orange; lower: sulphur yellow; fades gradually to chalky white; falls from tree; very rare on live conifers	Conk indicates total cull. Where decay present in basal scar, 4-6 ft. above top of scar.
Hetero-basidion Root and Butt Rot	*Heterobasidion annosum*	Root rot of all conifers, (rare on Douglas-fir in California), butt rot mainly in true firs	Heartwood and sapwood, butts, and roots	Conks, scars, signs in nearby stumps, logs, windthrows	White pocket rot, small elongated pockets, black flecks; delamination of growth rings	Annual, irregular, shelving or flat. Upper: brown; lower: white with sterile margin, small pores. In stumps, under bark of dead and dying trees	Butt, except in over-mature red fir, where may go 20-25 ft.
Shoestring Root Rot	*Armillaria* spp.	Most conifers, oaks	Heartwood and sapwood, butts and roots	Nearby dead oaks, resin-soaked wood, mycelial fans, zone lines, rhizomorphs	White pocket rot; yellow, stringy, wet with zone lines	Annual mushroom, clustered, present in fall; honey-colored to dark brown, thick tapering stem; rare on live trees	In stands where known to occur, 6-12 ft. where scars are present

Table 8 continued. Common Wood Decays of California

Red Ring Rot (*Phellinus pini* and *P. cancriformans*)

Hosts: *P. pini* infects Douglas-fir, western larch, pines, hemlocks, spruces, true firs, western red cedar and rarely incense cedar. *P. cancriformans* is found on true firs.

Distribution in California: *P. pin*i is found statewide and *P. cancriformans* is found in northern California and southern Oregon.

Fruiting Bodies of *Phellinus pini*

Photo: Joe O'Brien

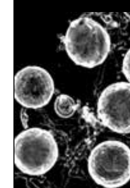
Characteristics: The fruiting bodies of *P. pini* are found on the boles of infected trees, often at branch stubs or knots. They are perennial, hard, and bracket- or hoof-shaped. Their upper surfaces are dark gray or blackish and concentrically furrowed. Lower surfaces and contexts (interiors) are cinnamon brown. The pores are irregular in shape. The fruiting bodies of P. cancriformans are similar, but generally smaller. They are produced in groups, usually on sunken areas on the host's lower bole. The color of the early stages of *P. pini* decay varies by host species. *P. cancriformans* causes decay that is light yellow or light brown to begin with. The advanced decay of both fungi is composed of spindle-shaped white pockets with firm wood in between. The pockets eventually coalesce in a honeycomb-like pattern. In the latest stages, the decay may form distinct rings or crescents (hence the name "red ring rot").

Disease Cycle: Fruiting bodies occur frequently on trees in older stands. The spores are dispersed by the wind. Infection is believed to occur when the spores germinate on dead branches or small branch stubs. The mycelia then grow through the branch stub and into the heartwood. Infections occur most frequently in dense stands where self-pruning creates entry points. Only live trees can become infected, although the decay can continue to develop in infected trees for a short time after they die.

Damage and Importance: *Phellinus pini* is more severe in older stands, in pure host stands, on steep slopes and on shallow soils. The decay is a cellulose and lignin-destroying white pocket rot occurring in the heartwood. The decay occasionally enters living sapwood. Larger conks of *P. pini* usually indicate more decay. Swollen knots fiilled with fungal tissue (punk knots) may be present on stems and are also indicators of decay. Punk knots are common in Douglas-fir, western larch, pines, and some spruces. The fungus is not a primary invader of dead wood and quickly dies in cut lumber. Unlike the cases with many other decays, wood decayed by this fungus maintains some strength against failure. *P. pini* is responsible for a large proportion of the decay of heartwood of live conifers in western North American forests because it is very common and has a wide host range.

Management Strategies: The management strategies described in the introductory section on Tree Decays apply to the management of Red Ring Rot (see pages 53-55) When this decay is encountered in developed recreation areas or high value sites, it should be evaluated carefully. This is because unlike many other wood decays, affected trees maintain some strength against failure.

Perceived Association with Cavity Nester Use: The level of use by cavity nesters is high when there is extensive advanced decay.



References

Hansen, E.M. and Lewis, K.L. editors. 1997. Compendium of Conifer Diseases. American Phytopathological Society Press. 101 p.

Harvey, R.D., Jr., and Hessburg, P.F., Sr. 1992. Long-range planning for developed sites in the Pacific Northwest: the context of hazard tree management. USDA, Forest Service, Forest Pest Management. FPM-TP039-92. 120 p.

Mallams, K.M., K.L. Chadwick and P.A. Angwin. 2010. Decays of white, grand and red firs. USDA Forest Service, Forest Insect and Disease Leaflet #52. 12 p.

Scharpf, R.F. 1993. Diseases of Pacific Coast Conifers. USDA, Forest Service, Agriculture Handbook #521. 199 p.

Rust-Red Stringy Rot (Indian Paint Fungus) (*Echinodontium tinctorium)*

Hosts: True firs and hemlocks are the main hosts; very rarely Engelmann spruce and Douglas-fir are also infected.

Distribution in California: Statewide

Fruiting bodies of *Echinodontium tinctorium*

Photo: US Forest Service

Characteristics: The fruiting bodies are perennial and hoof-shaped. They often appear underneath branch stubs. Their upper surfaces are dull, black, and rough. The lower surface on each conk is composed of hard teeth or spines that are gray when fresh and black when old. The context (interior) is bright orange-red. In the early stages of decay, the wood is soft and light yellow to brown. Rusty-red or black zone lines may appear. More advanced decay is stringy and brown or rust-red.

The fungus is a white rot fungus and thus can attack both wood cellulose and lignin. Initially it preferentially attacks the early wood (wood formed in early spring) causing the wood to become delaminated. Later, when this fungus attacks and shreds the residual late wood, it produces the rust red stringy rot that prompted its common name.

Disease Cycle: The perennial fruiting bodies can produce spores throughout the year when conditions are favorable, but the most active sporulation occurs during cool, wet, spring and fall months. The spores are primarily windborne and require exposure to subfreezing temperatures before germination. They infect small (less than two mm or 1/12 in diameter) exposed branchlet stubs just before these branchlets are overgrown. Suppressed and slow-growing trees tend to have more shade killed branchlets and heal branchlet stubs more slowly, allowing more opportunities for fungal infection and colonization. After spores have germinated and mycelia develop within the branch, fungal growth continues until the branchlets are overgrown The fungus then enters a dormant state as a resting spore that can survive for 50 years or more without causing decay. Dormant infections are activated by mechanical injuries, frost cracks, or formation of large branch stubs that allow air into the trunk interior. Wounds must be within about 30 cm (12 in) of dormant infections to activate them. Wound size is not important, however the larger the injury, the more likely that one or more dormant infections will be activated. Once the fungus is activated and enters the bole, decay develops rapidly. After extensive decay has formed, conks are produced, often at branch stubs and occasionally at wounds. Spores can be produced for several years after conks are formed and for as much as ten years from conks on trees that have died or been felled.

Damage and Importance: *Echinodontium tinctorium* is common in dense stands with suppressed trees that have small dead twigs and exposed branch stubs, especially on sites where tree vigor is low. Moist, cool sites (lower slopes, near water, north aspects, dense shade) and uneven-aged stands with true fir or Douglas-fir overstories are particularly favorable. Trees on densely shaded sites near trees with fruiting bodies will have the greatest numbers of infections.

Echinodontium tinctorium fungus causes heartrot. Even during the earliest stages, the wood may be significantly weakened (when milled it tends to separate during seasoning, causing ringshake). The rot is most common in the mid-trunk but may also extend into the butt or down from the top. In very late stages of decay, the trunk may become completely hollow. This fungus causes significant decay in older true fir and hemlock stands (>150 years), but younger stands can also be affected. Infected trees that break or are windthrown are important sources of hollow logs for wildlife habitat and act as nurse logs for regeneration.

Management Strategies: Decay caused by *E. tinctorium* is a major factor wherever advanced regeneration of true fir or hemlock is managed. Decay due to this fungus can be kept low by avoiding management of suppressed regeneration that has developed underneath infected overstories.

The presence of *E. tinctorium* fruiting bodies indicates extensive decay and high potential for stem breakage. In developed recreation areas, trees with fruiting bodies within falling distance of a target are considered highly hazardous.

Perceived Association with Cavity Nester Use: The level of use is high.

References

Etheridge, D.E., and Craig, H.M. 1976. Factors influencing infection and initiation of decay by the Indian paint fungus (*Echinodontium tinctorium*) in western hemlock. Canadian Journal of Forest Research. 6: 299-318.

Filip, G.M , Aho, P.E., and Wiitala, M.R. 1983. Indian paint fungus: a method for recognizing and reducing hazard in advanced grand and white fir regeneration in eastern Oregon and Washington. USDA-Forest Service, R6-FPM-293-87. 24 p.

Filip, G. M., Goheen D. J., and Kimmey J. W. 2009. Rust-red stringy sot caused by the Indian paint fungus. USDA Forest Service, Forest Insect & Disease Leaflet # 93 11p.

Filip, G.M., and Schmitt, C.L. 1990. Rx for *Abies*: Silvicultural options for diseased firs in Oregon and Washington. USDA Forest Service, GTR-PNW-252. 34 p.

Hansen, E. M., and Lewis, K.L. editors. 1997. Compendium of Conifer Diseases. American Phytopathological Society Press. 101 p.

Mallams, K.M., K.L. Chadwick and P.A. Angwin. 2010. Decays of white, grand and red firs. USDA Forest Service, Forest Insect and Disease Leaflet #52. 12 p.

Dry Pocket Rot (Pecky Rot) (*Oligoporus amarus)*

Hosts: Mainly incense-cedar; has also been found rarely in true fir

Distribution in California: Statewide

Pecky rot fruiting body on incense cedar

Photo: Bill Woodruff

Characteristics: The fruiting bodies are formed annually in late summer or fall. They are soft, moist, and hoof-shaped. They are bright yellow or buff colored when fresh. They often don't last long because they are quickly eaten by insects and rodents. Woodpeckers search for insects at the site of conks that have been eaten, leaving depressions in the bark that are good indicators of infection. Incipient decay appears as a brownish discoloration. Eventually, elongated pockets develop. The wood in these pockets breaks down into a dry, dark brown, crumbly residue, separated by shrinkage cracks. Although the decayed pockets may become very numerous, they usually remain distinct from one another rather than coalescing into a single column of decayed wood.

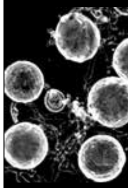
Disease Cycle: Most infected trees only produce one or two fruiting bodies. They are not produced until the decay has become extensive. They appear during late summer and fall and generally last only a few months. The spores are windborne. Fire scars, large open knots and stubs of large, broken branches are the most common means of entry for the spores. Infection is likely in trees with open wounds growing on sites where surface moisture lingers on exposed heartwood.

Damage and Importance: Pocket dry rot is most common in trees on good quality sites and on moist microsites. It is less common in trees on marginal sites near the eastern limit of incense-cedar's range where moisture and temperature conditions are less favorable for establishment of the fungus than in milder areas.

Oligoporus amarus causes a brown pocket rot of the heartwood. Incense-cedars less than 150 years old are usually relatively free of decay. The incidence of decay increases rapidly, however, in trees 200 years old and older. Decay is almost always present in incense-cedars larger than 100 cm (40 in) in diameter at breast height, and in trees with basal wounds or old, dead limbs. Breakage is relatively uncommon, even when decay is very advanced.

Management Strategies: Most of the management strategies described in the introductory section on Tree Decays apply to the management of Dry Pocket Rot (see pages 53-55). Because breakage is uncommon even when decay is extensive, this disease is seldom a problem in developed recreation areas.

Perceived Association with Cavity Nester Use: Use by cavity nesters is high, and increases with host age.



References

Scharpf, R.F. 1993. Diseases of Pacific Coast Conifers. USDA, Forest Service, Agriculture Handbook #521. 199 p.

Wagener, W.W., and Bega, R.V. 1958. Heart Rots of Incense-Cedar. USDA, Forest Service, Forest Pest Leaflet #30. 7 p.

Red-Brown Root & Butt Rot (Also Schweinitzii Root & Butt Rot, Brown-Cubicle Butt Rot, Velvet-Top or Cow Pie Fungus) (*Phaeolus schweinitzii)*

Hosts: Most frequently found on Douglas-fir. Also found on pines, spruces, incense cedar, western red cedar, true firs, and rarely on hemlocks.

Distribution in California: Statewide

Phaeolus schweinitzii fruiting bodies

Photo: US Forest Service

Red-brown root and butt decay, and fruiting bodies

Photo: Jim Byler

Characteristics: The mushroom-like fruiting bodies are the most reliable signs of infection. They are produced annually on the ground near the bases of infected trees. Occasionally, they occur on the stem, usually within 3 1/3 m (10 ft) of the ground. They are velvety in texture and reddish, greenish, or yellow-brown with yellow margins. Concentric rings are visible on the upper surface. As they age, they become dark brown, brittle and resemble cow-pies. Early decay is light green to light brown and firm. In advanced stages, the decay is light brown and cubical, aging to dark brown with resinous white mycelial sheets in the shrinkage cracks.

Disease Cycle: The fruiting bodies are produced in summer and fall, and may persist for a year or more. They tend to be more abundant on moist sites. Fruiting bodies near the bases of trees indicate that the roots are infected but do not necessarily indicate that extensive butt rot is present. Windborne spores colonize trees through root wounds and fire scars. Tree to tree spread also takes place across root contacts and grafts. The relative importance of these two different modes of infection varies by locality. Trees of any age may become infected.

Damage and Importance: *P. schweinitzii* causes a major root and butt decay of older trees. Wind breakage above the groundline is more common than windthrow. Trees are seldom killed as a result of root decay alone, but this does sometimes happen. Decay is confined to the heartwood and is usually found in the roots and butts of the host within ten ft (3 1/3 m) of the ground. However, decay may occasionally extend as much as 10 m (30 ft) up the trunk in trees greater than 150 years of age. Infected trees may have pronounced butt swells or “jug butts”. In very advanced cases, the heartwood may disintegrate completely, leaving a hollow butt. Trees in this condition often fail during high winds, leaving characteristic “barber chairs” and shattered butts.

Management Strategies: The management strategies described in the introductory section on Tree Decays apply to the management of red-brown root and butt rot (see pages 53-55). When red-brown root and butt rot is encountered in developed recreation areas or high value sites, trees should be carefully evaluated rather than automatically removed. Trees with seriously compromised anchorage should be removed or the hazard otherwise mitigated. Minimize infections by avoiding root and basal wounding.

Perceived Association with Cavity Nester Use: The level of use by cavity nesters is probably low because the decay is restricted to the base of the stem.

References

Allen, E.A., Morrison, D.J., and Wallis, G.W. 1996. Common tree diseases of British Columbia. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia. 178 p.

Hagle, S.K. and Filip, G.M. 2010. Schweinitzii Root and Butt Rot of Western Conifers. USDA Forest Service, Forest Insect and Disease Leaflet # 177. 8 p.

Harvey, R.D. Jr., and Hessburg, P.F. Sr. 1992. Long-range planning for developed sites in the Pacific Northwest: the context of hazard tree management. USDA, Forest Service, Forest Pest Management. FPM-TP039-92. 120 p.

Mallams, K.M., K.L. Chadwick and P.A. Angwin. 2010. Decays of white, grand and red firs. USDA Forest Service, Forest Insect and Disease Leaflet #52. 12 p.

Brown Trunk Rot (Quinine Fungus) *(Fomitopsis officinalis)*

Hosts: Douglas-fir , pines, western larch, spruces, and hemlocks, occasionally on true fir

Distribution in California: Statewide

Fruiting body of *F. officinalis*

Photo: Natural Resources Canada

Characteristics: While the fruiting bodies are not now common in California they were traditionally associated with old growth Douglas-fir. When present they are hard, hoof-shaped and chalky-white or gray, with ridged, cracked surfaces. They may become long and cylindrical after several years. Incipient decay varies in color by host species from purple to brown or yellow. In advanced stages, the wood breaks down into crumbly masses of yellow-brown to reddish-brown cubical chunks. Thick, whitish mycelial felts are common in the shrinkage cracks between the cubes. These felts become quite thick (about 5 mm or 1/5 in) and may cover a large area in one continuous sheet. Felts have a bitter taste that is characteristic and are often associated with resinous pockets or resinous crusty areas. While the decay and felts may not be easily distinguished from those of the more common (in California) sulfur fungus (*L. sulphureus*) the quinine taste of the felts can be used to distinguish the two.

Disease Cycle: The fruiting bodies are perennial. They are formed relatively frequently on western larch but are uncommon on other host species. The presence of one fruiting body indicates that most of the heartwood is decayed. The spores are windborne. The fungus generally colonizes hosts through wounds, branch stubs, or broken tops and occasionally through fire scars.

Damage and Importance: This fungus is most commonly found in old-growth conifers. Its incidence in second-growth forests is not well known but appears to be low. The fungus is usually associated with the trunk and upper boles of trees. It is rare in the butt. The decay is frequently diffi to detect in its early stages. The stems of trees with heartwood decayed by this fungus are very prone to breakage.

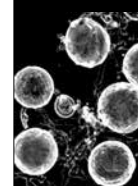
Management Strategies: The management strategies described in the introductory section on Tree Decays apply to the management of Brown Trunk Rot (see pages 53-55). The presence of F. officinalis fruiting bodies indicates extensive decay and high potential for stem breakage. In developed recreation areas and high value sites, trees with fruiting bodies within falling distance of a target are considered highly hazardous.

Perceived Association with Cavity Nester Use: High

References

Allen, E.A., Morrison, D.J., and Wallis, G.W. 1996. Common tree diseases of British Columbia. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia. 178 p.

Scharpf, R.F. 1993. Diseases of Pacific Coast Conifers. USDA, Forest Service, Agriculture Handbook #521. 199 p



Brown Cubical Rot (Sulfur Fungus) *(Laetiporus sulphureus)*

Hosts: Douglas-fir, true firs, pines, hemlocks, spruces, larch, western red cedar, and a number of hardwoods including oaks, maples, birch, and willow.

Laetiporus sulphureus fruiting bodies

Photo: Don Owen

Distribution in California: Statewide

Characteristics: The fruiting bodies are fleshy, soft, clustered and shelf-like. They are produced annually, appearing in late summer and fall at or near the base of infected trees and stumps. Fruiting bodies are edible and are commonly harvested They are brilliant orange to red-orange above with bright sulfur-yellow pore surfaces when fresh. When old, the fruiting bodies become hard, brittle and chalky white. Incipient decay appears as a light brown stain. In advanced decay, the wood breaks down into reddish-brown cubes. The cracks between the cubes may be filled with nonresinous, white mycelial felts.

Laetiporus sulphureus fruiting bodies

Photo: Don Owen

Disease Cycle: The fruiting bodies are produced annually in the fall, often in large, spectacular clusters. They only appear when a significant amount of decay has already developed in a host. The spores are windborne. The fungus enters trees through basal fire scars and through other wounds and branch stubs on conifers.

Damage and Importance: : This fungus causes brown cubical rot in a variety of tree species. It causes considerable rot in true fi Although it is not considered a major slash decay organism, it is often seen on stumps, logs, and dead trees. The fungus decomposes cellulose in the heartwood and occasionally sapwood, causing a brown cubical rot. Decay most often occurs in the butts of trees. Occasionally, higher portions of the trunk will also be affected.

Management Strategies: The management strategies described in the introductory section on Tree Decays apply to the management of Brown Cubical Rot (see pages 53-55). The presence of *L. sulphureus* fruiting bodies indicates extensive decay and high potential for stem breakage. In developed recreation areas and high value sites, trees with fruiting bodies within falling distance of a target are considered highly hazardous.

Perceived Association with Cavity Nester Use: Unknown

References

Allen, E.A., Morrison, D.J., and Wallis, G.W. 1996. Common tree diseases of British Columbia. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia. 178 p.

Mallams, K.M., K.L. Chadwick and P.A. Angwin. 2010. Decays of white, grand and red firs. USDA Forest Service, Forest Insect and Disease Leaflet #52. 12 p

Gray-Brown Sap Rot (Pouch Fungus) (*Cryptoporus volvatus)*

Hosts: A wide range of conifers, including Douglas-fir, true firs, spruce, western hemlock, lodgepole, ponderosa and western white pine, western larch, and incense cedar.

Distribution in California: Statewide

Characteristics: The fruiting bodies are small, round and leathery. They are buff-colored or brownish when fresh and become white and papery when old. A small opening develops on the underside of each fruiting body with time, exposing the brown inner pore layer. Initially, decay develops in the outer sapwood and is grayish-white. In advanced stages, the wood becomes light brown and crumbly.

Cryptoporus volvatus fruiting bodies

Photo: Joe O'Brien

Disease Cycle: The short-lived fruiting bodies usually develop the year after a tree dies. They often occur in great numbers on the stem. Insects have been shown to play a role in the dispersal of the spores from these fruiting bodies. Transport of the spores by insects may account for the speed with which dead trees and especially bark beetle infested trees become colonized.

Damage and Importance: This fungus causes rot of the sapwood of recently dead, standing trees. For the most part, this fungus occurs only on dead trees, appearing within one to two years after the tree's death. It develops rapidly, but affects only the outer one to two cm (2/5 to ½ in) of the sapwood. The sapwood of trees killed by bark beetles is commonly decayed by this fungus. Because the decay develops rapidly, many beetle-killed snags disintegrate and fall relatively quickly. This fungus is also found in areas of dead sapwood in otherwise live trees, and in the sapwood of live, though weakened Douglas-fir infested by bark beetles.

Management Strategies: Because this fungus indicates the presence of bark beetles or other mortality agents, management is generally keyed to those agents. In developed recreation areas or high value sites, living trees with fruiting bodies on dead tissue should be assessed carefully, because failure potential increases directly with the circumference of dead tissue and depth of saprot. Dead trees within falling distance of a target are highly hazardous, regardless of whether *C. volvatus* is present or not.

Perceived Association with Cavity Nester Use: Moderate level of use by cavity nesters. Usefulness is probably short-lived since trees are likely to break and/or fall quickly.

References

Allen, E.A., Morrison, D.J., and Wallis, G.W. 1996. Common tree diseases of British Columbia. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia. 178 p.

Mallams, K.M., K.L. Chadwick and P.A. Angwin. 2010. Decays of white, grand and red firs. USDA Forest Service, Forest Insect and Disease Leaflet #52. 12 p.

Scharpf, R.F. 1993. Diseases of Pacific Coast Conifers. USDA, Forest Service, Agriculture Handbook #521. 199 p

Canker Diseases

Characteristics: A canker is a localized area of dead bark and cambium on stems or branches. The fungi that cause cankers are not usually aggressive pathogens, but can be damaging when the host tree is under stress from other factors, such as drought, fire, insects or other diseases. They enter susceptible tissues through wounds or other openings in the bark, such as branch stubs. Most canker fungi are restricted to bark and cambium tissue and do not penetrate into the wood.

Disease Cycle: Cankers are either annual or perennial. Annual cankers occur for one year or season only. Dead tissue is eventually sloughed off and the affected area becomes covered with callus in much the same way a wound is healed.

Damage and Importance: Fungi that remain active in trees for more than one year cause perennial cankers. Usually the radial growth of the tree exceeds the growth in canker size, thus preventing the tree from being girdled and killed.

Cankers do not normally reduce tree height or diameter growth, but may cause stem breakage, provide an entrance for decay organisms, and cause dieback of girdled tops, branches, or twigs. They are not a serious problem in western coniferous forests, but can present a threat to plantation, Christmas, ornamental, and other high-value trees.

Cytospora Canker (*Cytospora abietis)*

Hosts: True firs, rarely Douglas-fir

Distribution in California: Throughout the natural ranges of the hosts

Characteristics: Diagnostic symptoms include:

- Red flagged (dead) branches
- Sunken dead areas on the bark
- Exudation of resin at the canker site
- Small, dark, pimple-like fruiting bodies (pycnidia) embedded in dead bark
- Amber to orange thread-like spore masses exuding from pycnidia during moist weather

Damage and Importance: Cytospora canker is one of the more common and potentially damaging cankers of true firs in California. It occurs chiefly on trees that are off-site or under stress from factors such as drought, fire, insects, and other diseases.

There is a peculiar relationship between red fir dwarf mistletoe and Cytospora canker. Most red fir branches that have dwarf mistletoe infections also have Cytospora infections. Dwarf mistletoe infections are not always prerequisites for canker infections, but this combination of pathogens often kills branches on large trees and tops of small trees. On white fir, Cytospora cankers are not as commonly or consistently associated with dwarf mistletoe. Groups of cankered white fir without mistletoe infections often indicate that there is a root disease problem present. Each of these situations demonstrates that Cytospora canker is usually favored by stress situations. Although Cytospora is a weak pathogen it can cause serious damage, especially to red fir, if it is off site, mistletoe infested, and also drought stressed. Under these conditions, it can become attacked by the fir engraver bark beetle (Scolytus ventralis), and subsequent to this attack dead and declining tree may be attacked by the flatheaded fir borer (*Phaenops drummondi*). Thus it is best to view the drought/ Cytospora/ dwarf mistletoe/ bark beetle scenario as being a decline complex.

Heavy infestation of cytospora canker of true fir

Photo: Dave Schultz.

Branch flagging and mortality of red fir caused by Cytospora canker in association with red fir dwarf mistletoe

Photo: John Pronos

Management Strategies: There are no direct control measures for Cytospora canker, but certain actions, when feasible and appropriate, may help to lessen damage. During logging operations, keep damage to residual trees to a minimum. Remove dwarf mistletoe-infected trees, and trees with Cytospora cankers. Avoid managing or planting firs on poor, unsuitable, or marginal sites. On recreation sites, prune and destroy infected branches. White fir can also have true mistletoe infestations by *Phoradendron pauciflorum*.

.

Atropellis Canker (*Atropellis pinicola*, *Atropellis piniphila)*

Hosts: Sugar, western white, ponderosa, and lodgepole pines (*A. pinicola*); lodgepole pine (*A. piniphila*).

Distribution in California: Throughout the ranges of the hosts (*A. pinicola*); from the northern limit of the host range to the northern Sierra Nevada (*A. piniphila*).

Blue-stained wood beneath *Atropellis* cankered bark

Photo: US Forest Service

Symptom of *Atropellis* canker

Photo: US Forest Service

Characteristics: Although there is only one common name (Atropellis canker) it is actually two diseases caused by two different fungi on two different groups of hosts. Lodgepole pine is the only host to be attacked by both fungi.

Diagnostic symptoms and signs include:

- Girdling cankers that kill distal portions of the branch, resulting in branch flagging (*A. pinicola* on all hosts)
- Large, elongate, sunken, resin-soaked perennial cankers on trunks and branches (*A. piniphila* only found on Lodgepole pine)
- A bluish-black wedge-shaped stain of the wood under the dead bark

Fruiting bodies of these fungi are black cup-shaped structures (apothecia) that are 2-5 mm in diameter.

There are very similar looking cankers produced by some rust fungi. However the Atropellis cankers can be identified by the fruiting bodies or presence of the blue-stained wood beneath the cankered bark.

Damage and Importance: *A. pinicola* primarily occurs on branches of young suppressed or weakened pines, or on shaded or suppressed lower branches of healthy pines. Trees seldom are killed or severely damaged. Infection by *A. piniphila* is often limited to trees growing on cool, moist sites, such as those in wet meadows and around lakeshores.

Management Strategies: Maintain vigorous trees in well-managed stands, encourage mixed species in stands, and maintain proper stocking levels.

References

Scharpf, R.F. 1993. Diseases of Pacific Coast Conifers. USDA, Forest Service, Agriculture Handbook # 521. 199 p.

Douglas-fir Cankers (*Diaporthe (Phomopsis) lokoyae* and *Dermea pseudotsugae)*

Hosts: Douglas-fir. Grand fir is an occasional host for *D. pseudotsugae*

Distribution in California: Throughout the host range; most common in the northern Coast Range

Characteristics: Symptoms of Phomopsis canker include:

- Sunken, elongate cankers resulting from initial infection of twigs, followed by growth of the fungus into the adjoining stem
- A distinct margin between infected and healthy portions of the stem

Symptoms of Dermea canker include:

- Branch and top dieback and tree mortality
- Cankers with a reddish margin when the tree is alive.

Dermea canker with bark removed

Photo: US Forest Service

Dermea canker

Photo: US Forest Service

Fruiting bodies of both fungi are small black pycnidia (0.5 – 1.5 mm in diameter) embedded in the dead bark. They can be seen in spring and early summer on cankered tissue. Microscopic examination of the spores produced in these fruiting bodies is necessary to distinguish between the two fungi. Cutting away *D. pseudotsugae* bark within a fresh canker will reveal a sharp reddish margin between healthy and diseased tissue. There is no reddish margin with *D. lokoyae* cankers. This color distinction is only noticeable with living hosts, for the red color is lost when the host dies.

Damage and Importance: Phomopsis canker is most severe on seedlings and saplings. It is generally not a serious problem in natural stands, but can cause serious damage in plantations and forest nurseries, especially when climatic conditions weaken the host. The annual canker does not kill trees larger than 3 inches DBH, but top and branch killing can occur.

Dermea canker is usually associated with stress, such as depleted soil moisture and frost. It affects principally sapling and pile-sized trees in both natural stands and plantations. Douglas-fir engraver beetle is often associated with the cankers, and tree mortality can occur.

Management Strategies: In nurseries, periodic spraying with protective fungicides throughout the growing season has been effective in controlling Phomopsis canker. Reducing vegetative competition, selecting against infected trees when pre-commercially thinning, and planting non-susceptible species can manage Dermea canker.

Nectria Canker of Fir (*Nectria fuckeliana)*

Cluster of fruiting bodies of *N. fuckeliana*

Photo: J.R. Liberato

Fruiting bodies of *N. fuckeliana* on a stem canker

Canker associated with a pruned branch stub on the stem of *Pinus radiata*

Hosts: *N. fuckeliana* infects true firs and spruce in the northern hemisphere. The best known California host is white fir (*Abies concolor*). In New Zealand it has become a serious problem on Monterey pine (*Pinus radiata*).

Distribution in California: Northern Sierras and the Cascade Range

Characteristics: Diagnostic symptoms and signs include:

- Conspicuous trunk cankers, mostly on small, suppressed trees less than 6 in DBH.
- Fruiting bodies (perithecia) are minute, spherical, red-colored flasks which are found in clusters of 10-100 and those clusters can be 1 to 2 mm wide. Fruiting bodies are usually found around the canker margins and are found more commonly on dead trees.

Damage and Importance: Nectria canker is most often detected in overstocked stands where white fir is the major stand component. Nectria canker causes stem breakage following stand thinning. Close inspection often reveals perennial stem cankers at the center of the break point.

Infection is possibly through wounds or injuries caused by insects. The affected tissue is often attacked by the sequoia pitch moth, Vespamina sequoiae, which keeps the wound open and the wood exposed to decay fungi. Surveys suggest that the canker is probably present in most of the densely stocked true fir stands in the northern Sierra and the Cascade Range.

Management Strategies: When stands are thinned, cankered firs should be removed and not selected for leave trees.

References

Schultz, M.E. and Parmeter, J.R. 1990. A canker disease of *Abies concolor* caused by *Nectria fuckeliana*. Plant Disease 74 (2): 178-180.

Madrone Cankers (*Botryosphaeria dothidea*, (asexual stage = *Fusicoccum aesculi); Neofusicoccum arbuti (*sexual stage = *Botryosphaeria))*

Hosts: Pacific madrone, manzanita, coast redwood, giant sequoia, incense cedar, ceanothus, and other hardwoods.

Distribution in California: Coast Range from Del Norte County to Ventura County, and western Sierra foothills from Nevada Co. to Tuolumne Co.

Characteristics: Host symptoms include blackened, dead branches that look "burned" and dead tops of madrone and manzanita. The disease is an opportunistic fungus that kills water and shade-stressed branches. The fungus can exist in a latent state inside the tree until the tree becomes stressed, when its defenses are weakened. Then symptoms such as canker expansion and branch dieback are expressed and the fungus fruits on dead tissue.

Madrone canker (right branch) with "burned" appearance ending at branch collar, and Arbutus canker (left branch) with callus

Photo: Marianne Elliott, WSU.

Symptoms usually start at branch tips and progress downward into large stems. Dieback may appear to end at the branch collar. The advancing edge in large diameter branches or stems is wedge-shaped.

Another canker on madrones, called Arbutus canker, is caused by the fungus *Neofusicoccum arbuti*. This fungus also has a sexual stage in *Botryosphaeria*. This disease is seen most often in the northern part of the host range but is also present in California. Cankers on the main stem and large branches have prominent callus ridges, often with decay in older cankers. Younger branches can have dieback, shoot blight, and branch flagging.

Disease cycle: Wind-borne spores infect young branches and leaf petioles. Early infections appear as darkened spots several millimeters in size. Within a few years, infection advances into older branches and stems, causing branch or stem dieback. Branches become blackened and roughened as masses of pycnidia (small, spore producing fruiting bodies) protrude through the dead and blackened bark. Dense canopy and understory vegetation provide the high humidity conditions that are ideal for disease infection and spread.

Shoot blight caused by *Neofusicoccum arbuti* with dead leaves attached and branch cankers on Pacific madrone.

Photo: Marianne Elliott, WSU.

Damage and Importance: Advancing spread of the disease can lead to unsightly branch flagged trees or entire tree mortality. Wildland or ornamental settings with multiple hosts may have unacceptable disease or mortality levels. Dead, standing hosts may add to increased fuel levels and possibly fire risk.

Management Strategies: For ornamental trees, prune and destroy infected small branches. On larger diameter branches, external discoloration may lag behind internal disease advance, and thus internal wood discoloration. Prune back to the next branch juncture whereby there is no discolored wood evident in the cross section of the cut.

Avoid pruning in wet weather because the wound may become contaminated while making the cut. Disinfect pruning tools after each branch cut. To keep reinfection at a minimum, remove or prune all nearby infected plants. Bury or burn all pruned wood residue. Reduce all competition to allow trees maximum light, air movement, reduced humidity, and freedom from root competition. Do not irrigate trees in a lawn situation. Avoid compacting soil over roots, such as in driveways or areas of heavy foot traffic. Maintain trees in a healthy, but not overly vigorous condition to lessen the opportunity for successful infection. No chemicals are registered for the control of this disease.

For a complete review of this summary, see CA Dept. of Forestry and Fire Protection's Tree Note #16 at: http://ceres.ca.gov/foreststeward/pdf/treenote16.pdf.

Seiridium Canker (Cypress Canker) (*Seiridium* spp. (usually *S. cardinale*))

Hosts: Monterey and other cypress spp., Leyland cypress, coast redwood, and Port-Orford-Cedar, and rarely incense cedar and giant sequoia.

Distribution in California: Most notable in coastal counties and interior to the San Francisco Bay area.

Characteristics: Branch and stem cankers cause fading and dead twigs, branches and tops of trees. Small trees can be killed. Sunken, resinous cankers and associative bark cracking are found at the point of dieback. The freshly exuded resin on the edge of cankers is often amber-colored.

Seiridium canker on Port-Orford-cedar; Note distinct margin between diseased (purplish) and healthy tissue, and resin exuding from the sunken canker

Photo: Katy Mallams

Disease cycle: Fungal spores are spread by wind and rain splash. The spores may enter through insect feeding wounds, or various other wounds, as well as unwounded branches often at the base of the branch or in branch forks. The spores can also enter through young leaves and shoots. Canker growth is greater lengthwise than radially around the branch, often leading to a slow dieback of the branch, causing fading, off-colored branches rather than quickly girdled, red branches. Fruiting bodies form at the cankered site, and their spores renew the infection cycle. The disease eventually blocks water and nutrient flow in the plant.

Seiridium canker on Port-Orford-cedar

Photo: Pete Angwin

Damage and Importance: Ornamental trees with multiple branch infections may become unsightly, and stem cankers, or multiple stem cankers, may cause tree death. Disease occurrence appears to increase with ornamental plantings in hot, low humidity settings. The disease is not prevalent in vigorously growing, native stands. Drought stress can increase the rate of canker growth. Infected cypress trees may have further branch and stem mortality by associative attacks of cypress beetles.

Management Strategies: Infected branches may be pruned from the trees. Prune well back of cankers, and sanitize pruning tools between branches. Remove pruned branches from the site (do not compost on site). Combine pruning strategy with irrigation of ornamental hosts during hot, dry periods. Avoid causing wounds on branches and stems. Along with pruning, remove and destroy heavily infected trees to reduce inoculum source.

References

Scharpf, R.F. 1993. Diseases of Pacific Coast Conifers. USDA, Forest Service, Agriculture Handbook #521. 199 p

Diplodia Blight *(Sphaeropsis sapinea (Diplodia pinea))*

Hosts: Most pines are susceptible. Ponderosa pines in the Coast Range and at lower elevations on the west-side of the Sierras and Cascades have experienced the most damage.

Distribution in California: Statewide

Tip dieback on ponderosa pine caused by *Sphaeropsis sapinea*

Photo: Don Owen

Diplodia symptoms on crown of ponderosa pine

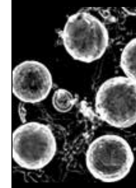
Photo: Don Owen

Characteristics: The principal symptom is death of developing shoots. Infected shoots have green needles in the spring, but hot weather causes the needles to dry and brown by summer. Heavily infected trees may appear to be dying, but closer inspection reveals that dieback is primarily limited to new shoots. Aresinous canker occurs in the dead tissue. The following combination of symptoms is diagnostic:

- Shoots are killed before the needles have completely elongated.
- Resin-soaked bark and wood occur in the dead shoot. The color of this tissue varies from amber to nearly black.
- The dead branch tip typically includes the current year's shoot, and may or may not include a portion of the previous year's growth. Older, non-resinous portions of the branch support live, green needles.
- Red/brown needles indicate an infection in the current year. Needles turn grey and often remain attached to shoots that have been dead for a year or more.
- There is no evidence of insect attacks on the dead shoots.

Disease cycle: The fungal pathogen can infect new needles and shoots, older woody tissue through wounds, and cones. Wet spring weather promotes infection. Pycnidia (= the asexual stge), a minute fungal fruiting body, may be produced on any of these substrates, usually in the spring of the year following infection. Spores produced by pycnidia cause new infections under favorable environmental conditions.

Damage and Importance: Shoot dieback varies from year to year and from tree to tree. Infection is often heavier in a given portion of a tree's crown. Wet spring weather during shoot elongation favors infection. Once this susceptible period has passed, additional shoot infections are unlikely for the remainder of the year. The disease is not systemic,



so annual dieback is dependent on new shoot infections. The disease is more common and generally more severe on mature and over-mature trees. In areas where Diplodia blight is common, individual trees may decline due to repeated infections and a small proportion of these may die. Repeated infection of individual trees appears to be a combination of the trees genetic susceptibility and its microenvironment in the spring.

Management Strategies: Direct control through the application of preventative fungicide treatments may be warranted for high value trees. Sanitation is the most appropriated treatment for a stand. Trees that suffer significant amounts of crown dieback and exhibit little or no recovery in subsequent years should be evaluated as candidates for removal.

References

Owen, D.R. 1998. Diplodia blight of pines, caused by *Sphaeropsis sapinea (Diplodia pinea).* California Dept of Forestry and Fire Protection Tree Note No. 23. 2 p.

Scharpf, R. F., 1993. Diseases of Pacific Coast Conifers. USDA Forest Service Ag Handbook # 521 199pp

Wood, D. L., Koerber T. W. , Scharpf R. F., & Storer A. J. 2003. Pests of the Native California Conifers. CA natural Histiory Guides. UCLA press. 323pp.

Pitch Canker (*Fusarium subglutinans*, sp. *pini)*

Hosts: In California the disease is common on Monterey pine, knobcone pine and bishop pine. It is less common but also found naturally on grey pine, shore pine, Torrey pine, Coulter pine, ponderosa pine, Aleppo pine and Douglas-fir. Laboratory tests show that other native and exotic pines in California may also be susceptible including Jeffrey pine and sugar pine. The disease is common in the southeastern United States on slash pine and loblolly pine.

Distribution in California: Coastal areas from San Diego County in the south to southern Mendocino County in the north. The disease is especially prevalent in both native stands and planted Monterey pine. One isolated infestation in the Sierra foothills in El Dorado County on Douglas-fir was eradicated.

Characteristics: Infections by pitch canker occur on branches, shoots, cones, exposed roots and boles of pines, and result in the formation of resinous cankers. Removal of bark from the canker reveals slightly sunken, honey-colored wood that is soaked with resin. The needles distal to branch tip infections wilt, fade, and fall from the tree. Multiple branch tip infections often result in a noticeable dieback in the tree crown. Western gall rust, Diplodia blight, other pathogens, and twig beetle injury can look like pitch canker, so laboratory isolations are necessary to confirm identity of the pitch canker fungus.

Pitch canker infection on a Monterey pine seedling

Photo: Jack Marshall

Pitch canker on the bole of Monterey pine

Photos: Don Owen

Disease Cycle: The life history of pitch canker is complex and not well understood. There are several spore types (macroconidia, microconidia, and mesoconidia) that can be seed-, soil-, and air-borne, or carried by insects. Wounds appear necessary for infection to occur. In California, infection occurs year-round but spore production appears heaviest during periods of high precipitation or high humidity. Pitch canker seems to need a relatively moderate, humid, coastal climate but the exact temperature and moisture requirements are not entirely known. In California it is only present less than 75 miles from the coast. Spread of the pathogen appears to be driven by insect populations.

Damage and Importance: Pitch canker is an introduced disease. It was first discovered in California in 1986 and was likely brought into the state from the southeastern United States. Since that time, pitch canker has killed thousands of ornamental and native Monterey pines of all ages. It has spread along the coast and now extends from San Diego to Mendocino. It has been damaging in the three remaining native Monterey pine stands in California (located at Cambria, Monterey, and Point Año Nuevo). Because the pathogen appears to be vectored by twig and bark beetles, it can race through an area, killing trees of all sizes. Monterey pine does not re-flush following infection.

Pitch canker is impacting the urban forest of many communities in California and is increasing fire hazard in infested areas. Property values are affected; property owners in Cambria must list pitch canker as a defect in property disclaimer statements when they sell property. Large amounts of contaminated, dead woody material are causing landfills to overfill and counties are being fined for lack of compliance with California mandated recycling laws. The California Native Plant Society has petitioned the state of California to list Monterey pine as a threatened species. Monterey pine seed imports to New Zealand have been banned. Milling and shipping of Monterey pine products in California has stopped due to contamination concerns. Utility line clearance is being hampered by large numbers of dead Monterey pines adjacent to high voltage lines.

Branch kill on Monterey pines infected with pitch canker

Photo: Don Owen

The pitch canker fungus is an exotic pest in California ecosystems. A majority of Monterey pines are susceptible to the disease, but individual trees vary considerably in the amount of damage they sustain during the course of an outbreak. A small percentage of trees are resistant and never develop disease symptoms. Trees with heavy levels of infection are at risk for being killed by bark beetles, while those with light to moderate levels of infection are likely to recover over time.

Management Strategies: Plant pathologists are breeding trees resistant to pitch canker for replanting in devastated areas. Non-susceptible hosts such as Monterey cypress and redwood can be planted where suitable. Management efforts are also focused on educating arborists and the general public to prevent spread of the pathogen via movement of firewood, Monterey pine Christmas trees, wood waste, pine needles used for landscaping, etc. It is important to avoid any further introductions of the disease to California to maintain the low genetic diversity of the fungus and reduce the opportunity of the disease to adapt to other areas of the state. Conservationists are also trying to increase the amount of land area in native Monterey pine stands that is protected from development.

References

Owen, D. and D. Adams. 2001. Impact of pitch canker on ornamental Monterey pines in Santa Cruz County, California, U.S., 1987-2000. J. of Arboriculture. 27(6):298-305.

Storer, A. J., T.G. Gordon, D. L. Wood, and P. L. Dallara. 1995. Pitch canker in California. (California Forestry Note No. 110. November.) California Department of Forestry and Fire Protection. Sacramento, CA.

More information on pitch canker can be found at the Pitch Canker Task Force Web site: http://frap.cdf.ca.gov/pitch_canker

Foliage Diseases

Elytroderma deformans infestation on ponderosa pine

Photo: Stuie Andrews

Needle diseases are principally a result of infection by fungi, although some abiotic factors may cause similar symptoms. Most needle diseases affect their hosts by reducing the photosynthetic area available to the plant, resulting in reduced growth rate. Degradation of quality can be a concern in Christmas tree plantations and other high-value sites due to the unsightly appearance of infected trees.

Most needle diseases of conifers attack either current year foliage or older foliage, but rarely both. Also, sporulation, spread, and infection of these fungi are frequently restricted to a specific season, and successful infection occurs only when conditions such as microclimate and developmental stage of the susceptible tissue are favorable. These rather rigid requirements for infection often result in only occasional years of heavy infection. Thus, mortality caused by these diseases is rarely a problem.

Table 9. Important Needle Diseases of California Confers

Important Needle Diseases of California Conifers

Disease/*Causal Agent*	Hosts	Comments
Elytroderma Disease *Elytroderma deformans*	Ponderosa, Jeffrey, Coulter, knobcone, lodgepole and pinyon pines	Has reached epidemic proportions in certain specific environments, such as around lakes and along stream bottoms
Sugar pine needle cast *Lophodermella arcuata*	Sugar Pine	More common in northern than southern CA; attacks only current-year needles; needle browning in spring
Red band needle blight *Mycosphaerella pini* *Scirrhia pini* *Dothistroma septospora*	Ponderosa, western white, lodgepole, knobcone, bishop, Monterey pines	Found in localized areas on the north coast
True fir needle cast *Lirula abietis-concolor* *Virgella robusta*	White, red, and grand firs	Attacks current-year needles; sporadic; important in plantations
Douglas-fir needle cast *Rhabdocline pseudotsugae* *Rhabdocline weirii*	Douglas-fir, big-cone Douglas-fir	Attacks one to several years' needles; severe on trees up to pole size; important mainly on Christmas trees

Elytroderma Disease (*Elytroderma deformans)*

Hosts: Although mainly a disease of ponderosa and Jeffrey pines. Elytroderma has been found on Coulter, knobcone, lodgepole and pinyon pines

Distribution in California: Scattered throughout most pine forests. The disease has reached epidemic proportions in certain specific environments, such as around lakes and along stream bottoms. Its concentration around lakes such as Lake Tahoe has considerable effect on the appearance of high-value recreational sites because of defoliation and tree death.

Characteristics: Diagnostic symptoms include:

- Reddening of needles in the spring
- Compact globose witches' brooms, with ends tending to turn upward
- Brown necrotic flecks in the inner bark of infected twigs
- Fruiting bodies of the fungus are elongate, narrow, dull black structures (hysterothecia), which can often, but not always, be found on needles; growing on all needle surfaces.
- Branch "flags" in spring

Witches broom caused by Elytroderma deformans. Note the upward turning branches with many dead needles

Photo: US Forest Service

Elytroderma deformans fruiting bodies (hysterothecia) on ponderosa pine

Photo: John Schwandt

Trees infected by *E. deformans* exhibit branch "flags" in spring. These are conspicuous clumps of reddened, dead one-year-old needles with green, current season's foliage at the tip. Small to large compact witches' brooms with upward turning branches and many dead needles develop when infection becomes systemic. These are sometimes confused with witches' brooms caused by western dwarf mistletoe and should be examined carefully. Inner bark of E. deformans-infected branches contains numerous dark, reddish- brown necrotic lesions. Elongated fruiting bodies develop on some dead infected needles in summer.

Disease Cycle: Spores are released in late summer and early fall from fruiting bodies (hysterothecia) borne on infected needles. The spores are carried by wind to current-year needles. Under proper microclimatic conditions, the spores germinate and infect these needles, which do not die until the following year. Unlike other needle pathogens, this fungus spreads throughout the needles and into the twigs. It can then spread further into growing tips and buds, infecting and deforming new growth. The microclimatic conditions favorable to infection are not well understood; however, certain areas, such as around lakes and along stream bottoms, appear to be more favorable to repeated infection.

Damage and Importance: Elytroderma disease is the most important needle cast disease of ponderosa and Jeffrey pines in western North America. It is most severe on seedlings, saplings, and poles with poor crowns

Elytroderma deformans infestation on ponderosa pine

Photo: US Forest Service

This fungus causes the premature death of 1-year-old needles and a brooming and deformation of infected twigs and branches. The effect of the disease depends on the proportion of the host's crown that is diseased. There is little effect upon the host until more than two-fifths of the twigs are blighted. Although this disease directly kills mature trees only infrequently, moderated to severe infection reduces growth and vigor and thus predisposes the host to other diseases and to bark beetle attack. Studies have shown reductions in radial growth up to 30 percent in trees with more than 50 percent of the foliage showing symptoms.

Management Strategies: In forest stands, control of elytroderma disease is rarely necessary or economical. In high-value stands, maintain proper stocking and eliminate trees of low vigor. Trees with *E. deformans*-caused branch flagging or witches' brooms within 6 feet of their leaders should be discriminated against in thinnings or harvest treatments. Offsite pine plantings should be avoided. Define high-risk areas following disease outbreaks, and regenerate with non-susceptible species.

Lophodermella Needle Cast (*Lophodermella cerina)*

Hosts: Lodgepole and ponderosa pines

Distribution in California: Modoc County to Fresno County

Characteristics: Affected needles turn brown in spring of the year following infection, and trees take on a scorched appearance. Needles are subsequently cast, and, if infected for several years, host trees develop a "lion tailed" appearance.

The fruiting bodies of this fungus are short, oval, light-brown to buff structures, and are easily overlooked on necrotic pine needles. At first, they are slightly darker and then the same color as the needle spot on which they occur. They develop in groups in buff to tawny waxy spots on live green or dead, reddish brown needles. The short concolorous fruiting body is the most distinctive characteristic of this fungus.

Pine needle casts are favored in situations where moist conditions prevail in early summer. Microsites, such as saddles where fog banks develop, borders of wet meadows, and riparian areas, contribute to higher risk than ridge top sites and upper slopes. Needle casts have their greatest impacts in pure, young stands or plantations, especially those established with offsite stock.

Lophodermella cerina infestation in a ponderosa pine plantation

Photo: US Forest Service

Disease Cycle: New host needles are infected by windborne and rain-splashed spores in early summer; only succulent, young needles are infected. Symptoms appear the year following infection. Infection is greatly favored by moist conditions.

Damage and Importance: This needle cast fungus is a native organisms that has coevolved with its hosts. Normally, impacts are light and occurrence is sporadic and strongly influenced by weather conditions. Needle casts can have very significantly influences, however, in offsite pine plantations, in unnaturally pure pine stands occurring on especially favorable sites for the pathogens, and in many stands during periods of unusually wet weather occurring over several years in a row.

Management Strategies: Usually, no special management actions are necessary for pine needle casts. Avoid planting offsite pine stock, especially in damp areas.

Red Band Needle Blight (Sexual stage = *Mycosphaerella pini (Scirrhia pini)*, Asexual stage = *Dothistroma septospora (D. pini)*)

Hosts: Attacks some 30 species, varieties, or hybrids of pine. Found on ponderosa, western white, lodgepole, Bishop, knobcone and Monterey pines, with Monterey x knobcone being some of the most susceptible.

Distribution in California: Statewide. Reported from north coastal California north into British Columbia and east to Idaho. Found to be damaging in only a few localized infection centers along the California coast

Mycosphaerella pini fruiting bodies cause distinctive red transverse bands

Photo: Bob James

Characteristics: The fungus infects needles of susceptible pines, causing them to die and drop off. Needles of all ages are susceptible. Under favorable environmental conditions, this disease can completely defoliate the host in a few weeks and eventually kill the infected trees. Monterey pine, although severely affected when young, becomes resistant after it becomes 20 to 30-years-old.

Symptoms first appear as yellow or tan spots at the site of infection. These spots turn a brownish-red and enlarge to produce the characteristic bands around the needles. Infection of current and second year needles is usually in the lower crown of sapling size trees. Seedlings and large trees are rarely infected. Newly infected needles have green bands that turn red or brown in late summer. These needles die from the tips back. Dead needles remain attached to the host and produce spores for about a year. Often nearly all the foliage on a tree becomes infected. Trees infected for several years often exhibit a “lion’s tail” appearance, with only a few needles remaining at the ends of branches.

Disease Cycle: Needles are infected during rainy periods by rain-splashed spores. The number of infection cycles depends on the climate. During wet years, several cycles of infection can occur. The *Dothistroma septospora* stage is the asexual, imperfect stage, and the one most commonly found. Small black fruiting bodies (pycnidia) develop in the centers of the red bands. Pycnidia are produced in abundance on infected needles. In the presence of free water, the pycnidia liberate spores that are splashed or blown to uninfected needles. Under moist conditions, the spores infect the new needles. The fungus grows within the needle tissue, killing the distal portion of the needle. Again, under favorable conditions, new pycnidia and spores are produced.

Damage and Importance: Several years of severe infection results in reduced growth and death of infected trees.

Management Strategies: Offsite pine plantings should be avoided. Define high-risk areas following disease outbreaks, and regenerate with non-susceptible species.

References

Peterson G. W. 1982 Dothistroma needle blight of pines Forest Insect and Disease Leaflet # 143. USDA Forest Service 6 pp

Scharpf, R. F., 1993. Diseases of Pacific Coast Conifers. USDA Forest Service Ag Handbook # 521 199pp

True Fir Needle Cast (*Lirula abietis-concoloris)*

Hosts: White and red fir. (also grand, noble and Pacific silver firs)

Distribution in California: Wherever hosts occur

Characteristics: Diagnostic symptoms and signs include, heavy dark brown or black elongate fruiting bodies (hysterothecia) which are found on the lower surface of second year needles. The fruiting bodies extend down the center of the lower needle surface for almost the full length. On the upper needle surface a thin brown line of asexual fruiting bodies (pycnidia) may form down the center of the needle for almost the full length. Crowns of heavily infected trees appear thin and more transparent than healthy trees.

Needle cast fruiting bodies on midrib of undersides of grand fir needles

Photo: US Forest Service

True fir needle cast on white fir

Photo: Dan Merritt

Disease Cycle: Field studies indicate a 2-year life cycle. Infection begins on young, developing needles during periods of rainfall. Fruiting structures mature on these needles the following spring and needles turn brown

Damage and importance: *Lirula abietis-concoloris* occurs sporadically and infects only newly emerged needles. Damage is rare since it takes several years of favorable weather for repeated infection to defoliate trees and affect growth and vigor.

Management Strategies: Because this disease occurs sporadically and seldom causes lasting or significant damage, management strategies to address this disease are seldom needed.

Similar Diseases: *Virgella robusta* – all the above hold true for *V. robusta* except that on the upper needle surface, TWO parallel rows of concolorous to brown pycnidia form instead of one along the length of the needle.

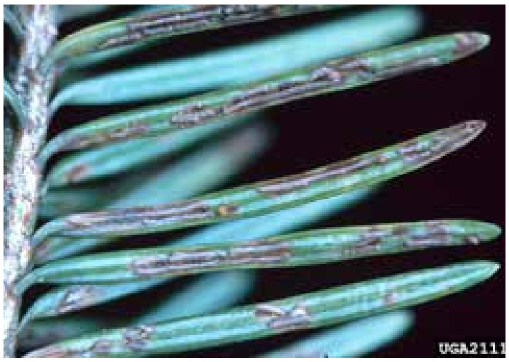
References

Scharpf R. F. (1988). Epidemiology of Lirula abietis-concoloris on white fir in California. Plant Disease 72:855-858

Rhabdocline Needle Cast (*Rhabdocline pseudotsugae* and *R. weirii)*

Hosts: Douglas-fir and big cone Douglas-fir

Distribution in California: Appears sporadically in most native Douglas-fir stands and Christmas tree plantations.



Fruiting bodies of *Rhabdocline pseudotsugae* on Douglas-fir needles

Photo: Petr Kapitola

Characteristics: The disease is characterized by yellowish to reddish-brown needle spots observed in the spring and elliptical, brown to reddish-purple fruiting bodies (apothecia) form on the undersides of infected needles in late spring to early summer. Fruiting bodies break open when mature to reveal orange spore-bearing surfaces. Later in the summer, infected needles are cast, so absence of a single year's needles is a common symptom at times of the year when needle spots and fruiting bodies are not evident. There is considerable variation in the susceptibility of Douglas-firs, with unaffected individuals often growing adjacent to trees that exhibit substantial defoliation.

Rhabdocline needle cast is common and widely distributed. Infection by *Rhabdocline* spp. is most common in years with wet springs and early summers. Microsites where conditions are particularly moist may exhibit higher levels of infection than drier microsites.

Disease Cycle: Fruiting bodies appear on the undersurface of needles infected the previous year and mature and release ascospores in May or June. These spores, carried by air currents, land on and infect the current-year's developing needles. Moist conditions favor infection. The fungus continues to develop in the newly infected needles through summer and fall. The first symptoms appear early that first winter as slightly yellowish spots at the site of infection. During the winter these spots become larger and more distinct. By spring the spots have changed to a deep red-brown color, and many of the spots have merged. In the late spring, elliptical fruiting bodies (apothecia) appear on the undersurface of the needle on either side of the mid-rib. These mature and sporulate in May or June, and the infected needles are cast during the following summer. It is suggested that those subspecies appearing on needles 2-years-old or older attack the current-year's needles but have a 2- to 3-year developmental cycle.

Damage and Importance: The *Rhabdocline* spp. are native pathogens that have coevolved with their hosts. The diseases they cause seldom seriously impact native Douglas-firs. They may, however, help to define the ranges of their hosts, since off-site plantings and Douglas-fir grown outside of the native range can suffer considerable growth loss and mortality.

Management Strategies: Usually, no special management is required for Rhabdocline needle cast. Severely infected trees may be removed during stand entries, especially thinnings. In native stands, there are almost always numerous unaffected or lightly infected trees to favor in the vicinities of any severely affected trees. Avoid off-site plantings of Douglas-fir; Rhabdocline needle cast and other diseases and insects can be very damaging in off-site plantations

Abiotic Diseases

Abiotic diseases are caused by non-living, non-infectious agents that physiologically or functionally impact a plant. They are results of stresses, either natural or man-induced, that occur in the environment.

Those diseases that result from aberrations in the natural environment usually cannot be diagnosed without an analysis of the past weather conditions. Sudden changes or abnormal occurrences in the area's weather are indicative of possible causes.

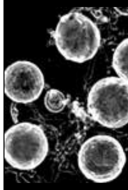
Evaluation of human-induced stresses requires examination of the physical environment associated with the affected plants plus past activities that might have had an adverse effect.

Diagnosis of abiotic diseases is complex and may require making some subjective determinations as to the effects of changes in the environment. Specific determinations of certain abiotic diseases (e.g., road salt, mineral deficiencies) may require laboratory analysis.

Most abiotic diseases do not act alone in damaging forests, but interact with other abiotic and biotic factors. They add additional stress to already impacted plants, or weaken them, resulting in predisposition to other pests and stressors.

An example of this in California was the 1975-77 drought. The lack of moisture weakened trees and predisposed them to bark beetle attack and subsequent mortality. However, the first trees to succumb were those already stressed by biotic factors, most notably dwarf mistletoe and root disease.

The following are various abiotic factors that can damage trees and reduce stand productivity. Included are symptoms that can aid diagnosis, and possible management tactics that can reduce their impact.



Air Pollution

Particulates/Dust: Of principal concern is road dust that covers foliage along well-traveled routes, but dust from hard rock mining operations can also impact vegetation locally. Heavy dust loads can reduce photosynthesis, damage the protective cuticle surface of leaves by abrasion, leaving them vulnerable to dessication, and in some cases such as limestone mining alter the environmental chemistry of foliage. Road dust also reduces populations of predators of the pine needle scale; scale populations can then increase resulting in growth reduction and, in extreme cases, mortality of pines.

In areas where trees are severely affected, treating roads to reduce the amount of dust or reducing traffic can limit further damage.

Sulfur Dioxide: Sulfur dioxide has been a local problem in areas adjacent to sites of fossil fuel combustion. Increasing use of high sulfur fuels may result in increased levels of damage. Most large emitters have reduced their output, but sulfur dioxide remains important for its role in acid deposition.

In conifers, symptoms first appear on older needle whorls, with symptoms progressing from the bottom of the crown to the top. Needles develop a reddish-brown discoloration in bands beginning at the needle tip. In broadleaved plants, leaves develop marginal and interveinal necrotic areas that can be bleached to tan to brown depending on the species. Their young leaves that have reached full size are most susceptible.

Maintain plant vigor to reduce injury to susceptible plants.

Ozone Air Pollution: Ozone is the main air pollutant currently affecting California forests. Southern California, especially the San Bernardino Mountains, is the most severely affected

Ozone injury on ponderosa pine

Photo: John Pronos

area, although injury symptoms have been found throughout the southern and central California provinces .

Species vary in their susceptibility to ozone damage. Individuals within a species also vary in sensitivity.

Following is a partial list of California forest trees grouped according to their sensitivity to ozone:

SENSITIVE: Ponderosa pine; Jeffrey pine; Monterey pine; California sycamore; quaking aspen; California black oak

INTERMEDIATE: White fir; incense-cedar; knobcone pine; Coulter pine; big-cone Douglas- fir; lodgepole pine

TOLERANT: Sugar pine; Douglas-fir; giant sequoia; redwood; western juniper; gray pine

Symptoms on pines, in order of increasing injury, include:

- Chlorotic mottle of foliage;
- Needle tip necrosis;
- Reduced needle length;
- Reduced needle retention;
- Abnormally high branch mortality;
- Reduced height and diameter growth;
- Increased root death; and
- Tree mortality

Symptoms on broad-leafed plants include:

- Water soaked appearance of upper leaf surface;
- Necrotic flecks on upper leaf surface;
- Chlorosis or bronzing of leaf;
- Premature defoliation; and
- Reduced growth

Areas that are only slightly affected should be monitored, keeping in mind the potential for increasing damage. In areas with moderate to severe impact, surveillance should be increased to detect any changes in injury levels. Resistant or tolerant species may be favored on sites to which they are well suited. Severely affected or dead trees may be removed. The appearance of ozone injury is highly influenced by environmental factors, and not all trees exhibit specific damage symptoms even though reductions in productivity may be occurring. Ozone must be absorbed through stomata before it can cause damage. In droughty years stomata may remain closed during most of the day reducing the uptake of ozone thus reducing visible symptoms in the current years needles of evergreen species. But since the damage is cumulative, evaluation of older foliage will provide clues to past exposure.

Chemical Exposure

Road Salt: The application of de-icing salt along roads can lead to needle tip dieback of nearby coniferous vegetation. Symptoms are usually evident within 100 feet of the road on the down slope side, although this distance may increase along drainages.

Salt damage along highway

Photo: John Kliejunas

Symptom severity generally decreases with increasing distance from the road. The tip dieback may be scattered or continuous throughout a tree, and results in a halo effect.

Spiraling of symptoms up through the crown occurs on true firs. Advanced symptoms include complete browning and tree death.

Suspected salt damage may be confirmed by consulting highway department personnel as to salt application and analyzing foliage for chloride content.

In damaged areas or areas prone to damage, the amount of salt reaching the vegetation can be reduced by diverting run-off, planting vegetation no closer than 30 feet from the road, and planting salt-tolerant species.

Herbicide Injury: Most herbicide injury is a result of improper application. Injury is usually found along roads, rights of way, fuel breaks, dwellings, or other areas where herbicides are often used.

Symptoms vary with the type and amount of herbicide used:

- Pre-emergence (e.g., simazine) – chlorotic banding at high rates.
- Post-emergence (hormonal, e.g. 2/4-D, 2/4/5-T, picloram, silvex) – abnormal growths, curled leaves, twisted petioles and needles, distorted shoots and twigs.
- Post-emergence (non-hormonal, e.g. amitrole, dalapon) – yellow-white bleaching chlorosis, and necrosis of tissues throughout crown.
- Contact (e.g., sodium arsenite, paraquat, Silvisar 510) – small necrotic spots on foliage resulting from drift.

Herbicide injury can be avoided by following label directions regarding the rate and method of application.

Moisture Extremes

Drought: Drought can be a local problem when plants are growing in soil with a low moisture holding capacity, or can be more widespread when insufficient precipitation occurs. Reduced moisture availability increases the susceptibility of plants to insects and diseases.

The extent of symptom development depends on the severity and length of drought. Long-term symptoms include poor needle retention, crown thinning and dieback. More immediate symptoms include include reduced shoot and needle elongation, and, in severe cases, needle discoloration and death. Small trees may be killed directly, while larger trees may be targeted by bark beetles. Severely impacted trees often recover slowly, exhibiting poor growth beyond

Drought damage; this tree shed its older needles first, but as the drought continued, the terminal and branch tips have died back.

Photo: Sue Hagle

the period of drought.

Maintaining proper stocking levels for the site can minimize the effects of drought. Proper management practices during periods of "normal" precipitation will also help to minimize the impact and levels of insects and diseases during periods of drought.

Drought is a well-known additive stressor. Drought will kill trees outright, particularly where the hydrology has been altered by stream bank channeling or changes to surface runoff and flow. But most often, drought acts in combination with insects and pathogens, causing serious mortality in forests. Precipitation records are an important tool in assessing the potential threat of drought induced damage and mortality.

Flooding: Flooding occurs periodically in nature along shorelines or riverbanks. It is not a common forest problem except near beaver ponds or around open meadows where high soil moisture occurs during the spring. Such situations may create stress and predispose trees to other factors. For example, flooded lodgepole pine may be predisposed to mountain pine beetle attack.

Flooding leads to tissue damage by depleting the oxygen supply to tree roots. This results in symptoms resembling those of some root diseases, ranging from yellowing or browning of foliage to mortality. Little can be done to alleviate the effects of flooding, other than salvaging severely affected individuals. Damage during construction of water impoundments should be avoided.

Maple Leaf Scorch: Maple Leaf Scorch (MLS) was first reported on bigleaf maple in Tulare and Plumas Counties in 'Forest Pest Conditions in California-1985'. Since the first report, MLS has been reported as being present in many areas in central and northern California. The reports attribute MLS to a combination of suspected causes such as desiccation (cool wet springs followed by hot dry windy summers), xylem-sucking insects, and/ or xylem-limited bacteria spread by those insects.

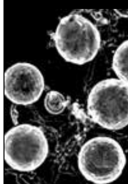
Typical big leaf maple with maple leaf scorch

Photo: Bill Woodruff

Typical symptoms include browning of the leaf margins, reduced leaf size and branch and stem dieback. From 1998 to 2008, MLS was informally monitored where MLS continued to reoccur, suggesting that the cause was biotic and not weather-caused. Although no data was recorded, MLS appears to have intensified over the decade as the affected trees continue to decline and in some cases have experienced nearly 90% crown dieback.

Temperature Extremes

Sunscald: Sunscald is a term which refers to the localized death of the cambium resulting from sudden exposure to direct sunlight following below freezing temperatures. Damage usually



occurs on the south or southwest side of the tree, and most commonly occurs within a few years after heavy thinning or selective cutting. The damaged tissue can provide an entry court for decay organisms. Sunscald is most common on thin-barked species, especially young growth Douglas-fir, true firs, sugar pine, western white pine and aspen.

Frost Injury: Damaging frosts typically occur in autumn (early frost) or spring (late frost), with the latter being the more common. Late frost kills active buds and shoots, while early frost kills shoots that have not yet hardened off. In addition to bud and shoot death, symptoms include needle reddening and shepherd's crooks (the curling of killed shoots).

Frost damage is usually associated with topographic depressions, or “frost pockets.” Most injury occurs within a few feet of the ground and adversely affects regeneration. Species vary in their sensitivity to frost. Following are some California species in order of increasing sensitivity: Lodgepole pine, Jeffrey pine, ponderosa pine, incense-cedar, sugar pine, and white fir.

In areas where frost damage is likely, regeneration may be protected by retention of a partial canopy until the understory has grown above the first few feet of the ground.

Frost Cracks: Frost cracks are vertical cracks which develop during periods of sudden cooling when tangential shrinking of wood is greater than radial shrinking. Such cracks are most common on older white firs, particularly on the east slope of the Sierra Nevada. Frost cracks provide entry courts for decay organisms and organisms that cause bacterial wetwood.

Symptoms of frost cracks include:

- Splitting of the wood along the bole, usually in the butt logs.
- Callus formation during the healing process.
- “Frost ribs” resulting from reopening of cracks in subsequent years.
- Slime flux exuding from old, partially healed cracks.

Trees affected with frost cracks may be discriminated against during thinning.

Winter Injury: Winter injury results in a desiccation of needles due to excess transpiration when the soil is frozen and warm dry winds occur. Winter-injured foliage becomes yellow to dark brown in the spring, and is most pronounced on the windward side of the tree. In extreme situations, injury can occur in all trees in an elevational band, resulting in a condition known as “red belt”.

Red belt is a form of winter injury / needle desiccation that is visible at a landscape level. The needles of individual trees desiccate and brown from the tip down. A swath or belt of trees is affected, typically following the contour of a side slope adjacent to a low-lying basin.

Unless extremely severe, winter injury does not affect buds and trees survive, although growth may be reduced. No special management techniques are necessary in most situations

Mechanical Injury: The accumulation of heavy, wet snow can cause bending and breakage of saplings and pole-sized trees, and top breakage of older trees. Snow loading of pinyon pine can lead to partially torn branches which (in the following spring) are attacked by several *Pityophthorus* species. Severely bent seedlings and saplings usually straighten out with no visible damage in later years, but height growth may

be reduced for several years. Pole-sized trees in dense stands, especially dominant individuals, are more susceptible to stem breakage. Dense sapling-sized stands should be thinned before the competition and struggle for light leads to tall spindly poles that susceptible to snow breakage, especially at high elevations where late wet snows occur.

Fire Injury: Excessive and prolonged heating of the bole, roots and foliage during prescribed or wildland fire can kill plant tissues, compromise structural integrity and result in tree mortality. Root collar injuries are often associated with the slow combustion of deep duff and litter layers. Crown injuries occur when high flame lengths, associated with ladder fuels, create excessive amounts of heat in the canopy. Crown injuries can also occur in dense canopies when fire spreads from tree to tree (active crown fire). A trees susceptibility to fire-injury depends on tree diameter, height, age and species. Fuel conditions and timing of fire can play a role in the amount of injury and subsequent insect activity. Trees that are not immediately killed by their fire-injuries may ultimately succumb to insects or diseases depending on the level of injury. Marking guidelines have been developed for California to help identify trees that are likely to die from fire-related injuries (Smith and Cluck 2011). Wounds created by fire can become colonized by decay fungi creating structural defects over time.

Fire damaged ponderosa pine

Photo: Danny Cluck

References

Jacobson, J.S. and Hill, A.C. eds. 1970. Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas. Air Pollution Control Assoc., Pittsburgh, PA. 102 pp.

Scharpf, R.F. and Srago, M. 1974. Conifer Damage and Death Associated with the Use of De-Icing Salt in the Lake Tahoe Basin of California and Nevada. USDA For. Serv., Pacific Southwest Region, For. Pest Control Tech. Rpt. 1. 16 pp.

Sinclair, W.A. and Lyon, H.H. 2005. Diseases of Trees and Shrubs. Cornell University Press, New York, NY. 660 p.

Smith, S. L. and D.R. Cluck. 2011. Marking guidelines for fire-injured trees in California. US Forest Service, Region 5, Forest health Protection, Report #RO-11-01. 15 p.

Forest Entomology

In forestry, insect-caused damage is quantified in terms of land use efficiency such as reduced yield or quality of a resource and increased costs associated with providing that resource. Forest entomology is concerned with the detection, identification, forecasting, and measurement of injurious insect populations; assessment of insect-caused damage, analysis of outbreak causes, and development and application of procedures for the protection of forest resources.

Within forests, insects occupy a wide range of micro-habitats. In the air within and above the canopy is the temporary habitat for flying stages of insects in active pursuit of mates, food, or egg-laying sites. The duff and soil layer contains numerous insects improving soil structure and fertility. All portions of the vegetation layers between house millions of insects that may be beneficial, injurious or benign.

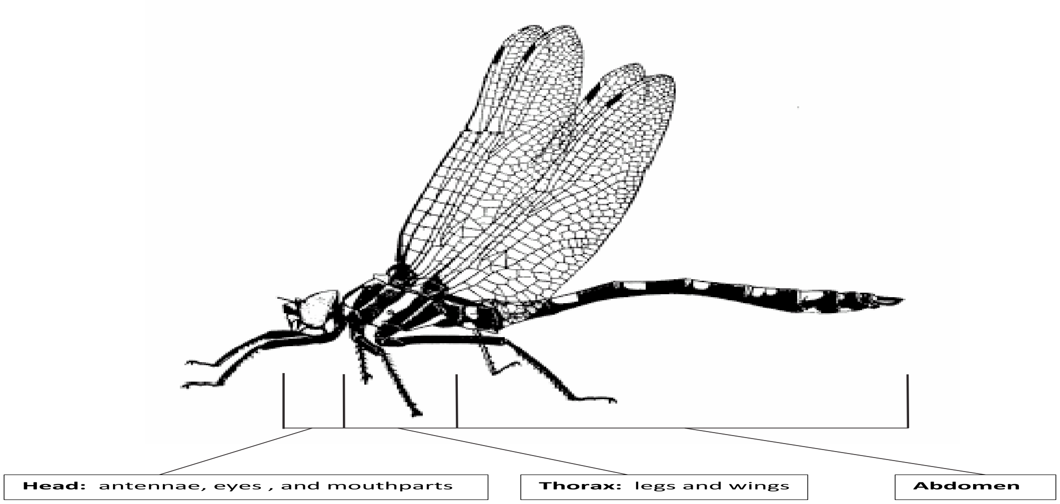
A common way of characterizing forest insect pests is by their feeding preference or guild. Thus there are defoliators, phloem and cambium feeders, wood borers, etc. All parts of a tree are subject to feeding damage. Some insect pests favor a certain age class of tree or forest stand. Insects that damage planted stands of seedlings to pole-size trees are referred to as plantation pests. Damage can occur to an individual tree or to many trees across the landscape. Ultimately, the impact of damage and level of response depends upon management goals for the property.

What is an Insect?

Insects are invertebrates belonging to the phylum Arthropoda, animals that are characterized by having a segmented body, a hard exoskeleton and jointed appendages. Insects (Class Insecta) can be further characterized as follows:

- the body is divided into three regions: the head, thorax and abdomen,
- there are three pair of legs originating from the thorax,
- many have one or two pair of wings, originating from the thorax, although some have no wings,

Figure 6. Anatomy of an insect



- the head has one pair of antennae.

Insect Classification and Identification

At the broadest level, insects sharing similar anatomical characteristics are grouped in to Orders, such as beetles (Coleoptera), moths and butterflies (Lepidoptera), true flies (Diptera), etc. These groupings are further narrowed in to Families (e.g. Curculionidae), Genera (e.g. Dendroctonus), and species (e.g. brevicomis)

There are many ways to identify an unknown insect, including:

- have it identified by an entomologist,
- compare it with labeled specimens in a collection,
- compare it with pictures or detailed descriptions,
- use an analytical key,
- or any combination of these procedures.

Insect Development

Insects change over time as they mature from egg to adult. These changes may be either gradual with the majority of change taking place in the relative size of the insect, or they may be spectacular as with the metamorphosis of a caterpillar into a butterfly. Two general categories of metamorphosis occur: simple and complete.

Figure 7. Simple Metamorphosis

Simple Metamorphosis: Egg ⇨ Nymph ⇨ Adult

The newly hatched individuals resemble the adult in general body form, but lack wings and external genitalia.

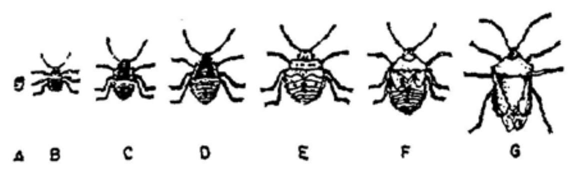


Figure 8. Incomplete Metamorphosis

Some aquatic insects undergo a more pronounced change from nymph to adult.

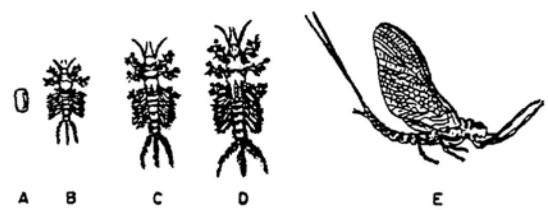
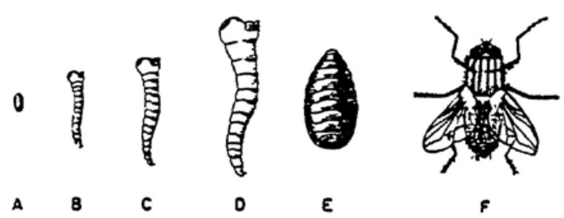


Figure 9. Complete Metamorphosis

Complete Metamorphosis: Egg ⇨ Larva ⇨ Pupa ⇨ Adult

Most species of insects undergo complete metamorphosis, which includes four developmental states: egg, larva, pupa, and adult.



Methods of Insect Control

Cultural Control Changes in stand conditions such as species diversity, age structure, and overall tree vigor through silvicultural methods including: • Rotation • Logging/Thinning • Slash Management • Salvage • Planting	**Mechanical Control** Options to physically stop injurious insects from moving from one place to another including: • Screens • Traps
Biological Control Using natural enemies to control an injurious insect, including: • Parasites • Predators • Diseases	**Chemical Control** Chemical compounds used to control the life cycle or behavior of injurious insects including those to: • Kill • Repel or attract (aggregating and anti-aggregating pheromones) • Sterilize • Trap Trees (integration of cultural and chemical controls)

Integrated Pest Management

A combination of techniques applied to manage insect populations at sub-economic levels, including the use of cultural, mechanical and biological methods as well as selective pesticides as needed. By recognizing significant interactions among the pest(s), host(s), and environment, the goal is to devise a strategy that is both environmentally sound and economically efficient. For a more comprehensive discussion of Integrated Pest Management, please refer to pages two and three of this document.

Insect Attack on Trees

Short-Term Effects

Direct Effects

- Loss of tree biomass in the form of foliage or other tissue
- Reduced height or diameter growth
- Reduced resistance to diseases and other pests
- Death

Indirect Effects

- Reduced recreational and aesthetic value of a site
- Increased fire hazard
- Altered habitat for wildlife through changes in stand structure or composition
- Altered forest management goals and costs
- Reduced grade of forest products
- Stress and anxiety in humans

Long-Term Effects

Both individual trees and the entire forest are affected:

- Increased biomass of residuals
- Increased height and diameter growth due to reduced competition
- Altered stand composition and structure
- Altered management goals

Insects Responsible for Tree Injuries

Table 10. Insects responsible for Tree Injuries

Injury/Signs/Symptoms	Pests Often Responsible
• Chewed foliage or blossoms	• Larvae of moths or butterflies • Sawfly larvae • Beetle larvae or adults • Tree crickets, grasshoppers, Walkingsticks • Snails and slugs
• Bleached, bronzed, silvered, stippled, streaked, or mined leaves	• Leaf miners • Leafhoppers • Lace bugs • Plant bugs • Thrips • Aphids • Psyllids • Spider mites
• Distortion (swelling, twisting, cupping of plant parts)	• Psyllids • Thrips • Aphids • Eriophyid mites • Gall makers
• Dieback of twigs, shoots, or entire plant; stems, branches, and exposed roots, sometimes hole in bark, wood dust, frass, gum, or pitch may issue from holes	• Wood borers • Bark beetles • Scale insects • Gall makers • Root-feeding beetle larvae
• Presence of insects, or insect related products on plants: • Honeydew and subsequent sooty mold	• Aphids • Soft scales • Leafhoppers • Mealybugs • Psyllids • Whiteflies

Insects Responsible for Tree Injuries cont'd

Injury/Signs/Symptoms	Pests Often Responsible
• Fecal specks on leaves	• Lace bugs • Greenhouse thrips • Some leaf beetles • Some plant bugs • Some sawfly adults
• Tents, webs, silken mats	• Tent caterpillars • Leaf tiers • Webworms
• Bags and cases	• Bag worms • Case bearers
• Spittle	• Spittlebugs
• Cottony fibrous material	• Adelgids • Mealybugs • Some aphids • Some scales • Some whiteflies • Flatid plant hoppers
• Slime	• Snails • Slugs
• Pitch tubes	• Some bark beetles
• Pitch or gum masses and sap flow	• Larvae of certain moths • Larvae of certain beetles • Larvae of certain midges

References

Furniss, R. and V. Carolin. 1977. Forest Insects. U.S. Dept. of Agriculture. Forest Service. Misc. Pub. No. 1339.

Borror, D., C. Triplehorn and N. Johnson, N. 1989. Insects 6th Edition. Saunders College Publishing. Orlando, Florida.

Johnson, W. and H. Lyon. Insects That Feed on Trees and Shrubs, 2nd Edition. Cornell University Press. Ithaca, New York.

Bark Beetles

Mountain pine beetle caused mortality in lodgepole pine, Modoc National Forest

Photo: Zack Heath

Bark beetles, family Curculionidae (subfamily Scolytinae), under favorable stand and climate conditions are the most destructive group of insects in coniferous forests of the West. Besides killing trees and breeding in the cambium of freshly felled trees and slash, some species bore pinholes through the sapwood of green logs and seriously reduce economic value. Other members of the group are secondary in their attacks (only infesting trees that have been attacked by other primary bark beetles), and some breed only in dead wood. There are hundreds of species of bark beetles found in the conifer forests of the West occupying a variety habitats ranging from cones to tiny branches to the main stems of their hosts.

Bark beetles are highly specialized to take advantage of ephemeral habitats. Trees that are suitable for successful beetle reproduction occur intermittently across the landscape and are only available for a limited time due to the drying of cambial tissue. Consequently, bark beetles have evolved a number of interesting adaptations that enable them to use these scarce and sometimes scattered resources. The most significant adaptation is the reliance on aggregation chemicals, or pheromones, produced by the attacking beetles to attract members of the same species to the host material. These aggregation pheromones allow the populations to fully occupy the ephemeral host material and, in the case of those species attacking live trees, to overcome the defenses of the host through mass attacks. Another adaptation is the close association of the insects with staining and wood decay fungi that the bark beetles introduce into the host plant. In some cases, these fungi make the host more palatable and nutritious for the developing beetles and may aid the beetle in overcoming host tree defenses.

Newly initiated *Ips* gallery with adults present

Photo: Scott Tunnock

The general method of attack is for the female beetle in monogamous forms, or the male in polygamous forms, to select a host and find a suitable place for starting the egg tunnels or galleries. The parent adults bore an entrance tunnel through the bark to the cambial region. As the work progresses, fine reddish-brown boring dust and excrement are extruded through the entrance hole and collect in the bark crevices or are combined with pitch that exudes from the entrance hole and hardens at the surface to form pitch tubes. These external signs are the first indicators that a tree is currently under attack by bark beetles.

Egg galleries are constructed in the cambial region (along the surface of the wood) and may or may not be packed with boring dust and excrement. Eggs are laid along the sides of these galleries and the larvae that hatch construct mines that lead away from the egg gallery. These mines are packed with excrement and boring dust. With some species of bark beetles, the larval mines are completely in the inner bark and are exposed when the bark is removed. Other species mine partially in the outer bark. The patterns of egg galleries and larval mines of many species are separate and distinct from one another, and are very useful in identifying the species of bark beetle. Pupation occurs at the end of the larval mine in a cell constructed by the larva for that purpose. This may be in the outer or inner bark. When the adult is fully mature, it emerges through a separate hole constructed through the bark.

Adults are small, cylindrical, dark reddish-brown to black beetles, ranging in size from 1 to 12 mm in length. Most species are one color, either shiny or dull. The head is either exposed or more or less hidden by the pronotum (dorsal part of the prothorax). The mouth parts are of the chewing type with well-developed mandibles. The antennae are elbowed at the middle and clubbed at the tip. The abdomen is completely covered by the elytra. Eggs are very small, clear or pearly white, and oval, round, or slightly elongated. Larvae are legless, cylindrical and curved, white or cream colored, with a distinct head and prominent mandibles that are dark colored. Pupae are white when first transformed, but gradually take on a yellowish color as they approach the time for transformation to the adult. The antennae, mandibles, legs, and wing pads are plainly visible on fully formed pupae.

Bark beetles spend most of their lives beneath the bark of their host and are only exposed to the outside world when they mature and disperse to find new hosts for the next generation. Adults may emerge at once and fly to attack new host trees, may congregate in cavities under the bark of the old host tree and hibernate, or wait until sexually mature before emerging. Most adults do a certain amount of feeding under the bark before emerging. A few, upon emerging, feed upon twigs, buds, or bark of other trees before breeding in a new host. These feeding galleries are quite distinct from the egg and larval galleries.

For most conifer species, there is at least one bark beetle species that is capable of killing the tree under the right conditions. Bark beetles that attack live trees are opportunistic and usually require their hosts to be under some form of physiological stress for colonization to be successful. Some of the typical agents of stress include drought, defoliating insects, various tree diseases that weaken the hosts, and a number of physical agents (air pollution, wind damage, etc.) which lower the natural defenses of the trees. Populations of these bark beetles can fluctuate dramatically from year to year depending on the degree to which stress agents are operating in the forest. The availability of suitable hosts is the ultimate regulator of bark beetle populations.

The economic and environmental impacts of bark beetle-caused tree mortality have led to various methods for controlling bark beetle populations and preventing successful attacks on individual trees and forest stands.

Direct control involves killing and reducing the population of bark beetles in an area. Direct control practices include trap and kill, fell-peel-burn, fell-deck-burn, fell-peel, fell-peel-spread bark, solar heat, and submerging the infested log in water. Most direct control treatments are very costly and time-consuming, and have not proven effective over large areas. These methods were mostly utilized in past management strategies and are now more appropriate for small-scale situations where only a few trees are infested.

Verbenone pouch stapled to lodgepole pine to prevent mountain pine beetle attack

Photo: Brytten Steed

Another method of direct control is the cutting and salvage of infested trees through logging operations. However, the primary purpose of salvage logging is the recovery of the economic value of wood fiber. Only under certain conditions does the removal of infested trees impact beetle populations. Removing green infested trees can be effective for certain bark beetle species (such as Jeffrey and mountain pine beetles) when beetle populations are small and localized. There also must be sufficient time to identify and remove infested trees before beetles leave the tree.

Preventative treatments such as spraying insecticides on tree boles are effective in protecting high value trees and logs. The use of insect anti-aggregation pheromones (such and verbenone or MCH) and non-host tree chemical compounds (such as non-host angiosperm volatiles) to protect high value trees have also shown efficacy in some situations. These methods are considered short-term treatments and are neither practical nor economical for large areas. They should also be used in conjunction with long-term vegetation management treatments such as forest thinning.

The best long-term approach to managing beetle populations is through preventative silvicultural practices. For the most part, this involves establishing vigorous, healthy trees and stands by maintaining the stocking, species composition and age at levels appropriate for the site.

Indicators for Bark Beetles, Engravers, and Flatheaded Borers

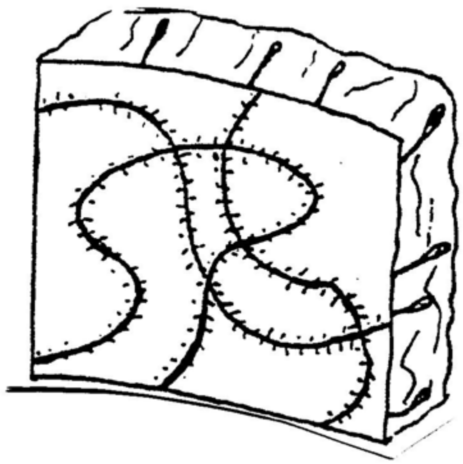
	Western Pine Beetle	Jeffrey Pine Beetle	Mountain Pine Beetle	Red Turpentine Beetle	California Five Spined Ips	Fir Engraver	California Flatheaded Borer	Fir Flatheaded Borer
Hosts	Ponderosa and Coulter Pine	Jeffrey Pine	All Pines Except Jeffrey Pine	All Pines	All Pines	Red and White Fir and Mountain Hemlock	All Pines	Red and White Fir, Douglas-fir
Portion of tree attacked	Entire bole to an 8” top	Entire bole to an 8” top	Entire bole to an 8” top	Generally, the basal 3’, root collar, and larger roots	Tops of large trees and entire bole of small trees	Tops, patches and entire bole	Entire bole and limbs	Entire bole and limbs
Pitch streamers, pitch tubes or boring dust	Pitch tubes (small) and boring dust	Pitch tubes (medium) and boring dust	Pitch tubes (small) and boring dust (red)	Pitch tubes (large), boring dust and coarse, crystallized resin granules	Standing trees – small pitch tubes (uncommon) and boring dust. Slash – boring dust	Pitch streamers and boring dust	Pitch streamers	Pitch streamers
Woodpecker work	Flaking in large patches – cambium not exposed	Individual holes to cambium layer	Individual holes to cambium layer	Individual holes to cambium layer	Flaking in patches – cambium partially exposed		Individual holes to cambium layer	

Table 11: Indicators for Bark Beetles, Engravers, and Flatheaded Borers

Western Pine Beetle (*Dendroctonus brevicomis*)

Hosts: Ponderosa pine and Coulter pine

Distribution in California: Throughout the range of suitable host trees.



Drawing of western pine beetle gallery.

Identification: Smallest of the western *Dendroctonus* species, this black cylindrical beetle is about the size of a grain of rice (4 mm long). Egg galleries are winding and packed with frass. Larval galleries lead away from the main gallery for short distances before turning into the outer bark. Small, reddish pitch tubes (sometimes fairly obscure) are signs of successful attack. Infested trees often exhibit woodpecker feeding with only portions of the outer bark removed. Sapwood of infested trees usually shows evidence of the characteristic bluestain associated with fungi introduced by attacking beetles.

Western pine beetle adult

Photo: Erich Vallery

Effects: Successful attacks result in death of the host tree. Trees are often killed in groups, especially when growing under crowded conditions. Since larger trees are generally preferred, the western pine beetle can dramatically alter the character of a forest that comes under attack.

Western pine beetle galleries

Photo: David McComb

Ecological Role: The western pine beetle is a key mortality agent for ponderosa pines weakened by the effects of old age, drought, smog, diseases, or competition with other trees. Stand structure can be altered and gaps can be created in the stand as the bark beetles kill larger trees, either singly or in groups. In those instances where ponderosa pine occurs in mixed stands with firs, the western pine beetle can accelerate the successional process by selectively removing the early seral species from the stand. Trees infested by the western pine beetle provide temporary food sources for woodpeckers and other insectivores. Infestation by western pine beetle sets the stage for other agents, such as wood borers and decay fungi that are involved in the recycling of nutrients back into the soil.

Life History: In the northern part of its range and at higher elevations, the western pine beetle completes two generations in one year, with adult beetles flying in early to mid June and mid to late August. In the southern part of its range and at lower elevations, the beetles produce three and sometimes four generations per year. Attacks may be as early as March and as late as November. Female beetles locate a suitable host and initiate attacks by burrowing through

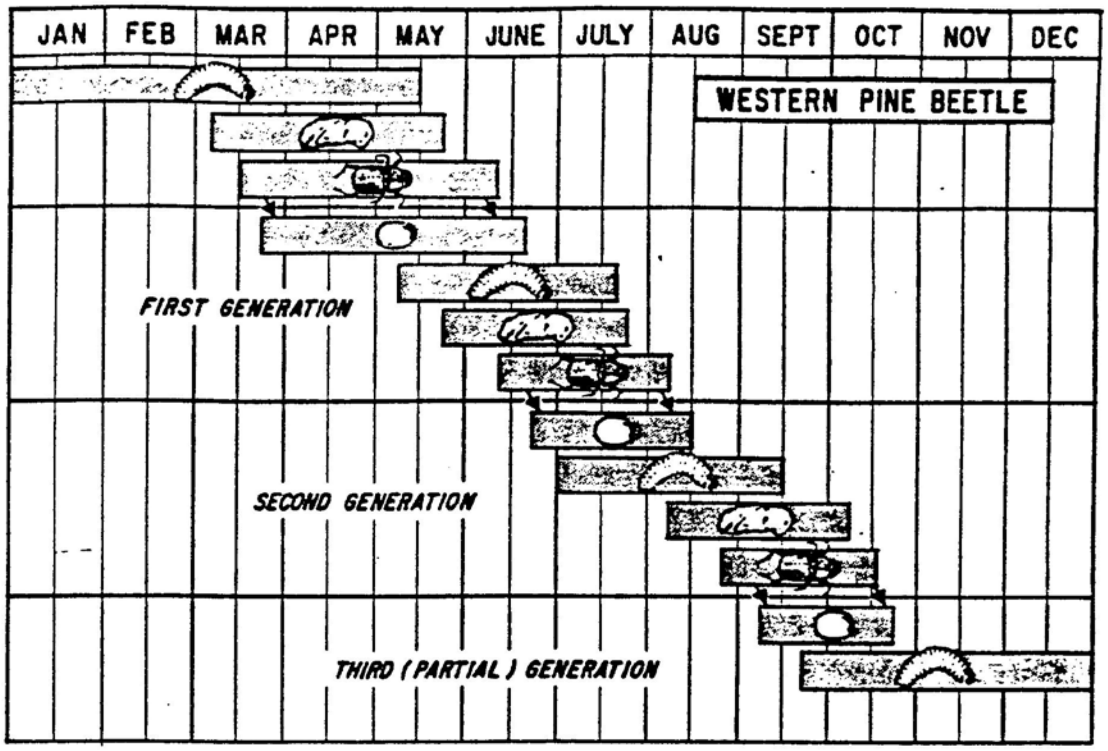


Figure 10. Life cycle of western pine beetle

the bark. They release an attractant pheromone that leads to mass attacks of the host tree and sometimes several trees in a group. Each female lays about 60 eggs in individual niches cut in the sides of the egg gallery. These eggs hatch in two weeks and young larvae feed initially in the phloem, later moving into the outer bark where most of their development takes place. After four larval stages, the insects pupate and then emerge as adults.

Conducive Habitats: The western pine beetle breeds most commonly in trees with reduced vigor due to old age, drought, disease, stand stagnation, or fire injury. While older, larger trees are generally preferred, younger trees can also be infested, especially when they occur in dense stands. During periods of drought, the western pine beetle may become particularly aggressive and overcome apparently healthy trees.

Similar Insects: Other bark beetles attacking ponderosa pine may be distinguished from western pine beetle by their egg gallery characteristics and adult appearance. Egg galleries of the mountain pine beetle are straight and vertical, and those of the engraver beetles possess a nuptial chamber with one to several tunnels radiating out from it. Pine engraver beetle (Ips) egg galleries are free of frass. Ips adults have a pronounced concavity at the rear end of the elytra that possesses three to six spines on either side. The rear end of *Dendroctonus* adults is rounded and does not possess any spines.

Management Strategies: The detrimental effects of western pine beetle can best be minimized by providing vigorous growing conditions for host trees. Stand densities below the "Upper Management Zone" (Cochran 1992; Cochran et al 1994) will provide sufficient growing space for trees and will minimize potential habitat for the western pine beetle. *Dendroctonus* beetle group-kills cause a limiting Stand Density Index of 365 that differs little between stands on good and poor sites in California (Oliver 1995). In the past, "high-risk" trees (those most likely to be infested by the western pine beetle) were identified by various hazard rating systems (Keen 1936; Salman and Bongberg 1942; Smith et al. 1981) and removed. Short-term treatments are also available to protect individual, high value trees such as spraying insecticides on tree boles to prevent bark beetle attacks. Other short-term treatment options for individual trees are currently being evaluated such as the use of anti-aggregation pheromones and non-host angiosperm volatiles. Tree injection systems are being explored to treat trees with systemic insecticides.

References

Cochran, P. H. 1992. Stocking levels and underlying assumptions for uneven-aged ponderosa pine stands. USDA Forest Service Pacific Northwest Research Station Research Note PNW-RN-509. 10 p.

Cochran, P. H., Geist, J.M., Clemens, D.L., Clausnitzer, R.R., and. Powell, D.C. 1994.

Suggested stocking levels for forest stands in northeastern Oregon and Washington. USDA Forest Service, Pacific Northwest Research Station. Research Note PNW-RN-513. 21 p.

DeMars, C.J., Jr., and Roettgering, B.H. 1982. Western pine beetle. USDA Forest Service Forest Insect & Disease Leaflet 1. 8 p.

Furniss R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA Forest Service, Miscellaneous Publication No. 1339. 654 p.

Keen, F. P. 1936. Relative susceptibility of ponderosa pines to bark beetle attack. J. For. 34:919-927

Miller, J. M. and Keen, F.P. 1960. Biology and control of the western pine beetle. USDA Misc. Publication 800. 381 p.

Oliver, W. W. 1995. Is Self-Thinning in Ponderosa Pine Ruled by *Dendroctonus* Bark Beetles? In: Eskew, Lane G. (comp.) Proc. 1995 Natl. Silviculture Workshop; Gen. Tech. Rep. RM-GTR-267. 246 p.

Salman, K. A., and Bongberg, J.W. 1942. Logging high-risk trees to control insects in the pine stands of northeastern California. J. For. 40:533-539.

Smith, R.H., B.E. Wickman, R.C. Hall, C.J. De Mars, and G.T. Ferrell. 1981. The California pine risk-rating system: its development, use and relationship to other systems. P 53-69 in: R.L. Hedden, S.J. Barras, J.E. Coster, Technical Coordinators. Proceedings of the symposium on hazard-rating systems in forest insect pest management, July 31-August 1 1980, Athens GA. General Technical Report WO-27. Forest Service USDA, Washington DC.

Mountain Pine Beetle (*Dendroctonus ponderosae*)

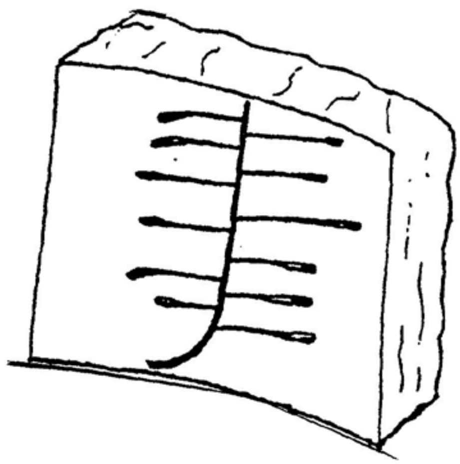
Hosts: Lodgepole, ponderosa, coulter, knobcone, western white, sugar, and whitebark pines. Mountain pine beetle has also been found attacking Pinyon pine in southern California.

Distribution in California: Throughout the range of suitable host trees.

Identification: The adult is a black, cylindrical, medium-sized bark beetle (5 to 7.5 mm long). The egg gallery in the inner bark is long and straight, oriented vertically, and has a slight J-shape at the base. They range from 10 to 122 cm in length and are packed with frass. Larval galleries extend at right angles from both sides of the parent gallery. The sapwood of infested trees exhibits bluestain caused by fungi carried by the beetles. Pitch tubes are generally visible on the boles of attacked trees. On successfully attacked trees, these are small, red and numerous. Pitch tubes on unsuccessfully attacked trees are larger in size (around 2 cm in diameter), typically white, and widely scattered over the trunk. During drought years, infested trees may not produce pitch, and external evidence consists only of boring dust. These are referred to as blind attacks.

Mountain pine beetle adult

Photo: Erich Vallery



Drawing of mountain pine beetle gallery

Effects: The mountain pine beetle ranks first in destructiveness among western bark beetles. In lodgepole pine, the mountain pine beetle attacks mature forests often over extensive areas. Attacks on other pine species may occur on either individual trees or groups of trees. Normally, the mountain pine beetle attacks trees that are under stress due to overstocking, or trees weakened by drought or disease. Periodically, large-scale outbreaks occur and infestations can extend into stands of healthy trees.

Mountain pine beetle caught in resin flow

Photo: Darren Blackford

Ecological Role: The ecological effects of mountain pine beetle differ depending on the pine host being considered. In lodgepole pine, the mountain pine beetle is the key agent responsible for recycling older stands. When a lodgepole stand is about 100 years old, the mountain pine beetle infests the largest trees and within a 3 to 4-year period, may kill nearly 80% of the trees in the stand. The advanced regeneration and smaller trees are all that remain after a typical mountain pine beetle event in this host type. In ponderosa pine, the mountain pine beetle is generally associated with fairly young trees (75-100 years old) and acts as a thinning agent in denser stands. This thinning may be fairly irregular and may involve sizable groups of trees but is generally far less dramatic than is the case with lodgepole pine. In the case of five-needle pines where host trees are usually scattered among other tree species, the mountain pine beetle will create small holes in stands as it attacks pines stressed by competition, white pine blister rust, or other factors.

Life History: In California, the mountain pine beetle typically has one generation per year, but at lower elevations and during years with warmer and longer growing seasons there can be two generations. Adult flight occurs between June and October. Females initiate attacks and release pheromones to attract males. Beetles create egg galleries in the inner bark and females lay eggs in niches along the side. The eggs hatch within 10 to 14 days and larvae begin feeding in the phloem. The winter is spent in the late larval stage and pupation occurs in the spring or early summer. By early-summer, callow adults form and new adults are ready to emerge shortly thereafter. Adults occasionally overwinter under the bark.

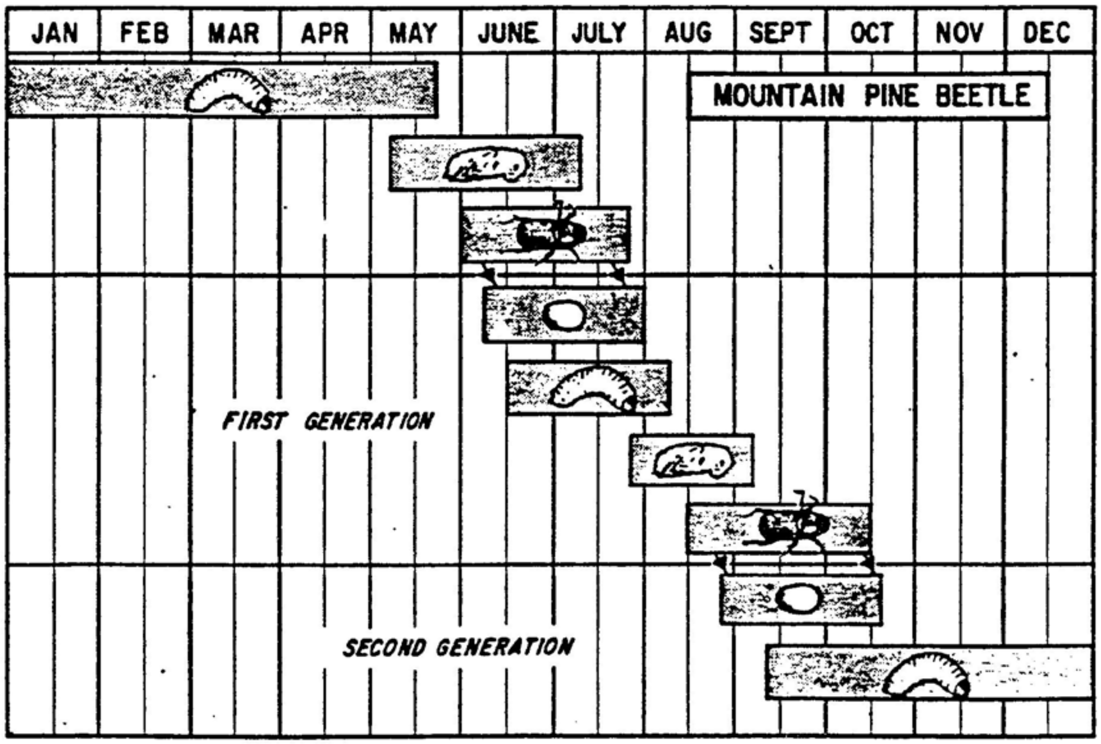


Figure 11. Life cycle of mountain pine beetle

Conducive Habitats: The mountain pine beetle is generally associated with trees under stress from such factors as competition with other trees, infection by dwarf mistletoe, root disease organisms, or other pathogens, or infestation by other insects. During drought periods, all of these factors become more important, and mountain pine beetle activity is at its greatest. In lodgepole pine, stands are highly unstable when they have 90-100 trees per acre that are greater than 9 in (22 cm.) in diameter. Second-growth ponderosa pine stands are likely to be infested when growth rates of codominant trees are less than ¾ in (19 mm.) in diameter for the last decade. Other species of pine are likely to be killed by mountain pine beetle when growing under dense stand conditions. Sugar pine infected with white pine blister rust or that have sustained fire injury are also highly susceptible to successful attacks.

Similar Insects: Jeffrey pine beetle (*Dendroctonus jeffreyi*) is very similar to mountain pine beetle in adult appearance and egg gallery pattern. However, it is only found in Jeffrey pine (not a mountain pine beetle host). Several other bark beetles may be found in common host tree species, including other *Dendroctonus* species and engraver beetles. These may be distinguished from mountain pine beetle by their egg gallery characteristics and adult appearance. Egg galleries of the western pine beetle are maze-like, and those of the engraver beetles possess a nuptial chamber with one to several galleries radiating out from it. Pine engraver beetle (Ips) egg galleries are free of frass. Ips adults display a pronounced concavity at the rear end of the elytra that possesses three to six spines on either side. The rear end on *Dendroctonus* adults is rounded and does not possess any spines.

Management Strategies: The mountain pine beetle is most effectively managed by providing vigorous growing conditions for host trees. The effects of mountain pine beetle can be minimized at the stand level by regulating stocking levels in accordance with the "Upper Management Zone" described by Cochran (1992) and Cochran et al (1994). The impacts of small localized populations may be reduced through the diligent removal of green infested trees. Short-term treatments are also available to protect individual, high value trees such as spraying insecticides on tree boles to prevent bark beetle attacks. Other short-term treatment options for individual trees are currently being evaluated such as the use of anti-aggregation pheromones and non-host angiosperm volatiles. Tree injection systems are being explored to treat trees with systemic insecticides.

References

Amman, G.D., McGregor, M.D., and Dolph, R.E., Jr. 1985. Mountain pine beetle. USDA Forest Service Forest Insect and Disease Leaflet 2. 11 p.

Amman, G. D., McGregor, M.D., Schmitz, R.F., and Oakes, R.D. 1988. Susceptibility of lodgepole pine to infestation by mountain pine beetles following partial cutting of stands. *Can. J. For. Res.* 18:688-695.

Anhold, J. A. and Long, J.N. 1996. Management of lodgepole pine stand density to reduce susceptibility to mountain pine beetle attack. *West. J. Appl. For.* 11(2):50-53.

Cochran, P. H. 1992. Stocking levels and underlying assumptions for uneven-aged ponderosa pine stands. USDA Forest Service Pacific Northwest Station Research Note PNW-RN-509. 10 p.

Cochran, P.H. and W. G. Dahms. 2000. Growth of lodgepole pine thinned to various densities on two sites with differing productivities in central Oregon. Res. Pap. PNW-RP-520. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 59 p.

Cochran, P. H., Geist, J.M., Clemens, D.L., Clausnitzer, R.R., and Powell, D.C. 1994. Suggested stocking levels for forest stands in northeastern Oregon and Washington. USDA Forest Service, Pacific Northwest Research Station Research Note PNW-RN-513. 21 p.

Furniss R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA Forest Service, Miscellaneous Publication No. 1339. 654 p.

McGregor, M.D., and Cole, D.M. 1985. Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA Forest Service Intermountain Forest & Range Exper. Sta. Gen. Tech. Report INT-174. 68 p.

Sartwell, C., and Stevens, R.E. 1975. Mountain pine beetle in ponderosa pine. Prospects for silvicultural control in second-growth stands. *J. For.* 73:136-140.

Schmid, J.M.; Mata, S.A.; Kessler, R.R.; Popp, J.B. 2007. The influence of partial cutting on mountain pine beetle-caused tree mortality in Black Hills ponderosa pine stands. Res. Pap. RMRS-RP-68 Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 19 p.

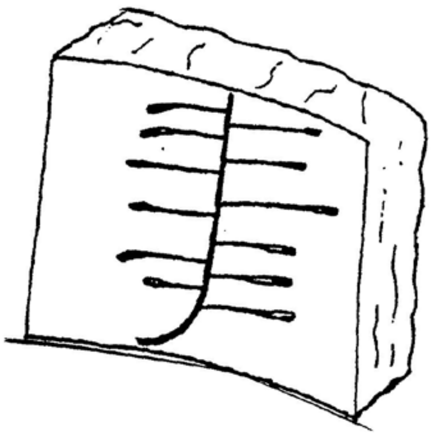
Wilson, I.M., Borden, J.H., Gries, R., and Gries, G. 1996. Green leaf volatiles as antiaggregants for the mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae). *J. Chem. Ecol.* 22: 1861–1875.

Jeffrey Pine Beetle (*Dendroctonus jeffreyi*)

Hosts: Jeffrey pine

Distribution in California: Throughout the range of Jeffrey pine.

Identification: The Jeffrey pine beetle is one of the larger *Dendroctonus* species, measuring from 6 - 8 mm in length. Adults are blackish in color. The egg gallery in the phloem and inner bark is long and straight, 30 to 90 mm in length, oriented vertically with a slight J-shape at the base and packed with frass. Larval galleries extend at right angles from both sides of the parent gallery. The sapwood in often discolored by bluestain fungi carried in by attacking beetles. Attacks generally result in relatively large pitch tubes or the accumulation of reddish boring dust in bark crevices.



Drawing of Jeffrey pine beetle gallery

Effects: Trees attacked by the Jeffrey pine beetle are most often killed. Attacks may occur on either individual trees or groups of trees. Normally, the Jeffrey pine beetle attacks trees that are weakened by pathogens, fire-injury, drought, lightning, or are under stress due to competition with other trees. Periodically, large-scale outbreaks can occur and infestations can extend into stands of healthy trees. During drought periods, all of these factors become more important, and Jeffrey pine beetle activity is at its greatest.

Larvae of Jeffrey pine beetle

Photo: Sheri Smith

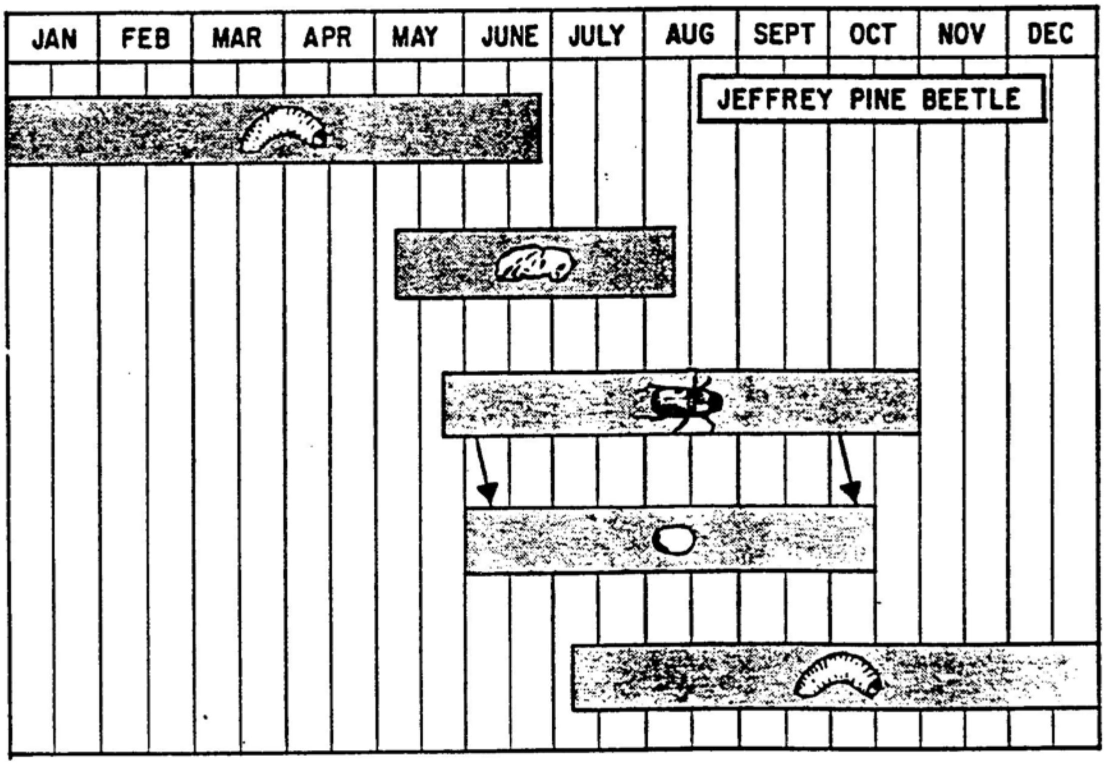
Ecological Role: Jeffrey pine beetle acts as a thinning agent in denser stands. This thinning may be fairly irregular and may involve sizable groups of trees. Jeffrey pine beetle caused tree mortality tends to be episodic and results in large group kills. Tree stressed by competition, disease or other factors are vulnerable to successful attack.

Jeffrey pine beetle pitch tube

Photo: Sheri Smith

Life History: The Jeffrey pine beetle has one generation per year in most northern and higher elevation locations within its range but two generations may occur during years with warmer and longer growing seasons in the southern portion of its range. Adult flight typically occurs between June and October. Females initiate attacks and release pheromones to attract males. Beetles create egg galleries in the inner bark and females lay eggs in niches along the side. The eggs hatch within 7 to 21 days and larvae begin feeding in the phloem. The winter is typically spent in the late larval stage and pupation occurs in the spring or early summer. However, the Jeffrey pine beetle can also overwinter in the adult stage.

Figure 12. Life cycle of Jeffrey pine beetle



Similar Insects: Mountain pine beetle (*Dendroctonus ponderosae*) is very similar to Jeffrey pine beetle in adult appearance and egg gallery pattern. However, it is not associated with Jeffrey pine. Other bark beetles may be found in Jeffrey pine such as the red turpentine beetle and engraver beetles. These may be distinguished from mountain pine beetle by their egg gallery characteristics and adult appearance. Egg galleries of the red turpentine beetle are short and irregular and those of the engraver beetles possess a nuptial chamber with one to several galleries radiating out from it. Pine engraver beetle (Ips) egg galleries are free of frass. Ips adults display a pronounced concavity at the rear end of the elytra that possesses three to six spines on either side. The rear end on *Dendroctonus* adults is rounded and does not possess any spines.

Mortality of large diameter Jeffrey pine caused by Jeffrey pine beetle

Photo: Sheri Smith

Management Strategies: The Jeffrey pine beetle is most effectively managed by providing vigorous growing conditions for the host trees. The impacts of small localized populations may be reduced through the diligent removal of green infested trees and insecticides can be applied to the bark of high value trees to prevent attacks.

References

Smith, R. H. 1971. Jeffrey Pine Beetle. Forest Pest leaflet 11. Washington, D.C.: USDA Forest Service.

Furniss R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA Forest Service, Miscellaneous Publication No. 1339. 654 p.

Red Turpentine Beetle (*Dendroctonus valens*)

Hosts: Most California pines

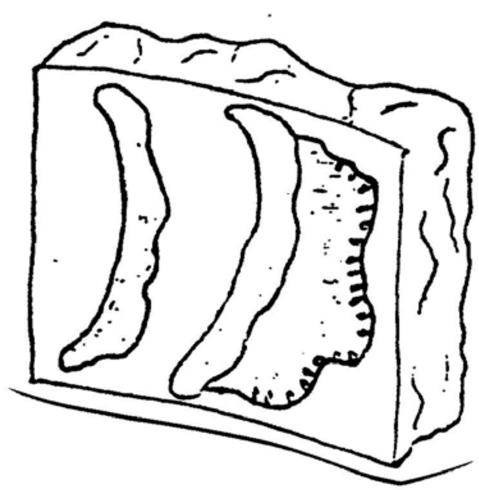
Distribution in California: Throughout the range of suitable host trees.

Adult red turpentine beetle

Photo: Joseph Berger

Attacks by red turpentine beetles immediately following fire

Photo: Sheri Smith



Drawing of red turpentine beetle galleries

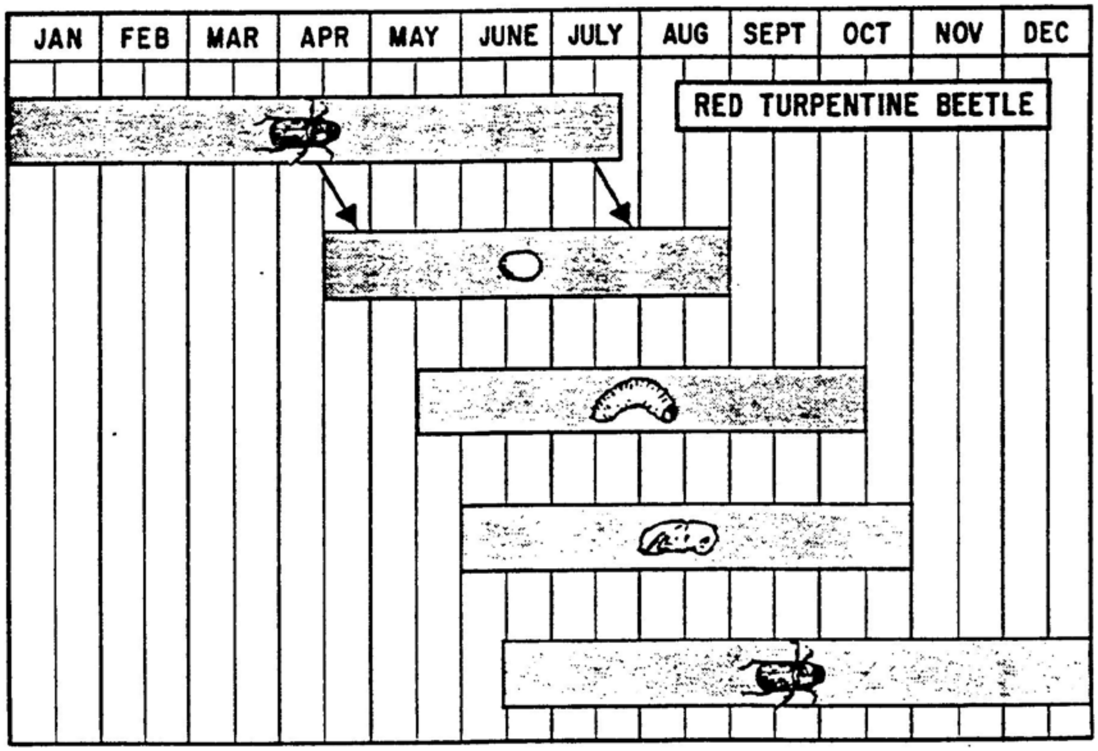
Identification: The red turpentine beetle is the largest of the *Dendroctonus* species, averaging 8 mm in length (some adults can be up to 12 mm in length). Adults are reddish brown in color. Attacks are generally confined to the lower bole and are easily recognized based on the large pitch tubes produced on the outer bark. These pitch tubes vary in size, texture and color, depending on the amount of bark and frass embedded in the resin, but typically are at least one inch (2.5 cm) in diameter. Attacks may also result in the accumulation of reddish brown boring dust at the base of the tree and in bark crevices and accumulations of creamy pink crystallized resin granules at the tree base. Eggs are laid along the edges of short, irregular galleries, although adults sometimes construct long galleries (up to 1 meter) starting at the base of the tree and extending down into the roots. Larvae feed communally, with each egg group excavating a single irregular shaped cavity under the bark.

Effects: Attacks by the red turpentine beetle are rarely lethal, although they may predispose the tree to further attack by other more aggressive bark beetles. The presence of red turpentine beetles is an indication that the host tree may have other problems. The role of the turpentine beetle is usually secondary to that of the other agents affecting pines. The red turpentine beetle readily colonizes freshly-cut stumps. During drought, RTB populations that develop in stumps may cause mortality of nearby pole-sized pines.

Life History: In California, adult beetles fly between May and September, probably arising from overlapping populations with one-year life cycles. Peak flight activity occurs in the spring when female beetles emerge from stumps or trees and fly in search of suitable host material. They burrow through the outer bark, are each joined by a male, and after mating, construct a short egg gallery between the bark and outer wood. Eggs are laid along the wall of the egg gallery and hatch within one to three weeks. Young larvae feed alongside each other in the phloem/cambial tissue. Once their feeding is complete, the larvae construct pupal chambers in the bark and transform into adults. Typically, the insects overwinter in the adult stage, although some overwinter as late-instar larvae.

Conducive Habitats: Any agent or activity that produces stress or pitch flow from the host tree is likely to invite attacks by the red turpentine beetle. Red turpentine beetles often attack trees infected by root disease pathogens, weakened by drought, attacked by other bark beetles, or wounded (especially if the wound resulted in sap flow). They are also commonly found on boles scorched by fire, on stumps of recently cut trees, and on the boles near the root masses

Figure 13. Life cycle of red turpentine beetle



on windthrown trees.

Similar Insects and Diseases: This beetle is distinguished from other bark beetles by the large size of the pitch tubes, gallery shape and the large size and reddish brown color of adult beetles.

Management Strategies: Minimize injury to standing trees and roots during logging, thinning, and road construction. High-value trees in intensively used areas such as campgrounds should be protected from injury and soil compaction. During drought, avoid thinning pole-size ponderosa pine in the spring and early summer (through June).

References

Barr, B. A., D. L. Hanson, and C. S. Koehler. 1978. Red turpentine beetle – a pest of pines. University of California, Division of Agricultural Sciences Leaflet 21055. 4 p.

Furniss, R.L., and Carolin, V.M. 1977. Western forest insects. USDA Forest Service Miscellaneous Publication 1339. 654 p.

Schmid, J.M., and Mata, S.A. 1991. Red turpentine beetles in partially cut stands of ponderosa pine. USDA Forest Service Rocky Mountain Forest & Range Exper. Sta. Research Note RM-505. 3 p.

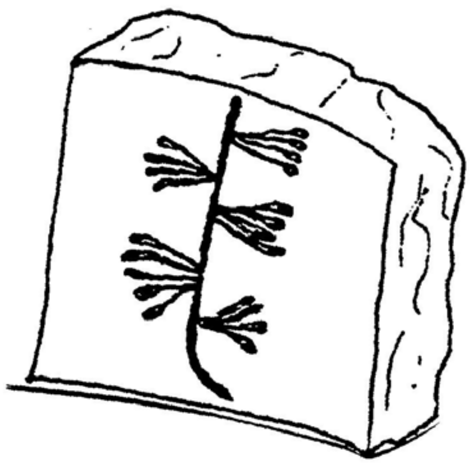
Owen, D.R., S.L. Smith, and S.J.Seybold. 2010. Red turpentine beetle. USDA Forest Service Insect and Disease Leaflet 55. 8 p.

Douglas-Fir Beetle (*Dendroctonus pseudotsugae*)

Hosts: Douglas-fir

Distribution in California: Throughout the range of Douglas-fir in the central to northern Sierra Nevada, southern Cascade Mountains, and Coast Ranges.

Identification: Adult beetles are dark brown to black with maroon-colored elytra, and are among the larger *Dendroctonus* beetles (8mm long). Other life stages are typical of most bark beetles. Parent galleries are formed between the bark and wood surface, and are straight and parallel to the grain of the tree. Eggs are laid in rows along alternating sides of the parent gallery. Larval galleries fan out from the parent gallery and end in a pupal chamber which may be located either in the phloem or the outer bark. Boring dust in bark crevices and at the base of a tree are signs of attack. There are generally no pitch tubes present, although resin may exude from attacks in the upper bole.



Drawing of Douglas-fir beetle gallery

Effects: The Douglas-fir beetle normally breeds in weakened or down trees. In certain instances when down or weakened host material is abundant, beetle populations can build to high levels and nearby standing trees may be attacked and killed. Outbreaks are sporadic and usually of short duration, subsiding after two or three years. Since the Douglas-fir beetle has a strong preference for the largest trees in a stand, even short-duration outbreaks can have a significant effect on stand structure through gap formation. Douglas-fir beetle is rarely a significant killer of standing trees in California except when associated with fire or windthrow events.

Douglas-fir beetle adult

Photo: Jed Dewey

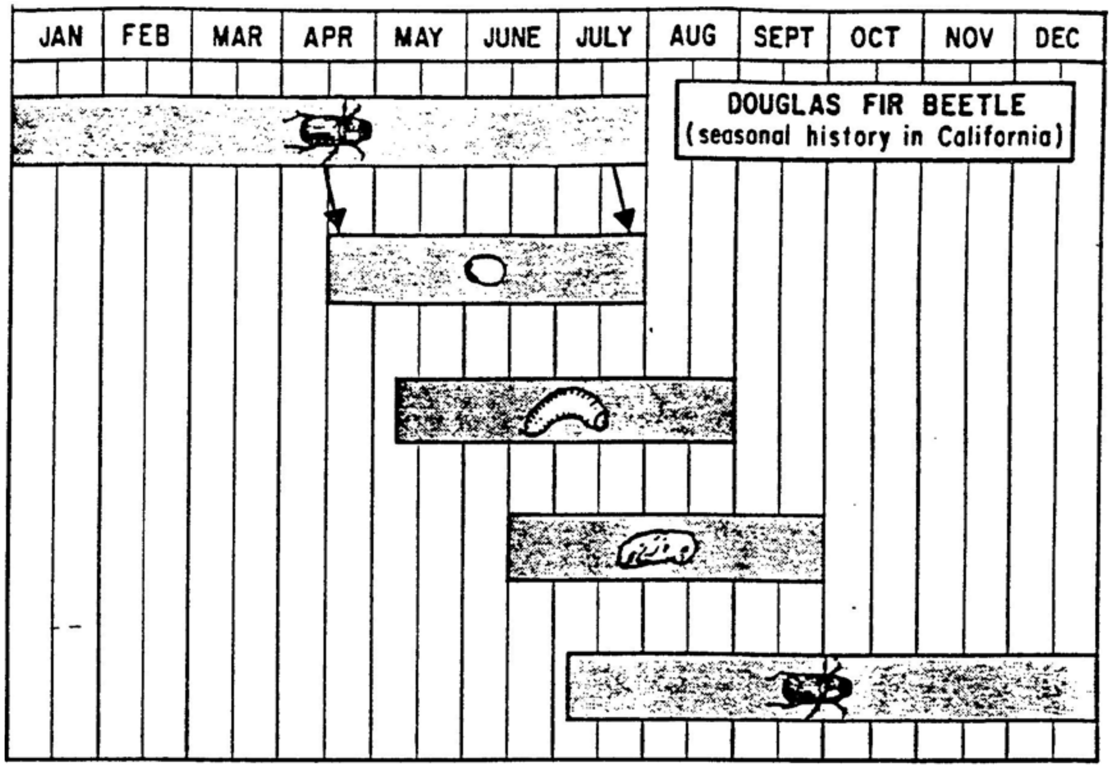
Douglas-fir beetle galleries

Photo: Brytten Steed

Ecological Role: The Douglas-fir beetle accelerates the rate of decomposition of down host material by introducing decay fungi and increasing access to the wood for other agents of deterioration. In standing trees, the Douglas-fir beetle is often the agent that kills trees weakened by other agents (defoliators, dwarf mistletoe, root diseases, drought). As such, it helps create gaps in the forest and causes changes in the species composition and structure in stands containing large Douglas-firs.

Life History: The Douglas-fir beetle has one generation per year. Adult flight usually takes place in the spring or early summer, whenever air temperatures exceed 15 C (60 F). Female beetles initiate attacks on suitable host material and construct long egg galleries beneath the bark. The eggs hatch within one to three weeks and young larvae typically feed in the phloem. Later in the larval stage, the larvae may enter the outer bark where they construct pupal chambers. The winter is spent either in the late larval, pupal, or adult stage. Those insects

Figure 14. Life cycle of Douglas-fir beetle



overwintering as adults will be the first to fly the following spring, and may re-emerge, fly again, and establish a second brood in late June or July.

Conducive Habitats: The Douglas-fir beetle depends on weakened hosts. Any condition that weakens Douglas-fir will lead to increased susceptibility to attack by the Douglas-fir beetle. It is generally believed that outbreak populations of the Douglas-fir beetle require some form of large-scale disturbance, typically, large-scale wind events, fires, or defoliator outbreaks.

Management Strategies: Direct control of the Douglas-fir beetle is seldom warranted. As with other bark beetles, the key to limiting populations of the Douglas-fir beetle is to provide good growing conditions for host trees. Because damaged hosts are very important in the population dynamics of this beetle, it is important to salvage this material promptly if avoiding infestation of surrounding trees is a desired objective. In some cases, the anti-aggregating pheromone (MCH) has been used to prevent colonization of down material and thus limit population growth of the bark beetle. MCH has also been shown to be effective in preventing attacks to standing trees. This technique is usually used to protect small areas of high-value trees.

References

Furniss, M.M. 1979. An annotated bibliography of the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk. USDA Forest Service, Intermountain For. and Range Exper. Sta. Gen. Tech. Rep. INT-48, 40 p.

Furniss, M.M.; Livingston, R.L., and McGregor, M.D. 1981. Development of a stand susceptibility classification for Douglas-fir beetle. In: Hedden, R. L.; Barras, S. J.; Coster, J. E., compilers. Proceedings: Symposium on hazard rating systems in Forest Pest Management, July 31-August 1, 1980. USDA Forest Service Gen. Tech. Rep. WO-27, 169 p.

LeJeune, R.R., McMullen, L.H., and Atkins, M.D. 1961. The influence of logging on Douglas-fir beetle populations. For. Chron. 37:308-314.

McMullen, L.H., and Atkins, M.D. 1962. On the flight and host selection of the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk. (Coleoptera: Scolytidae). Can. Ent. 94:1309-1325.

Ross, D.W., and Daterman, G.E. 1994. Reduction of Douglas-fir beetle infestation of high-risk stands by antiaggregation and aggregation pheromones. Can. J. For. Res. 24:2184-2190.

Schmitz, R.F., and Gibson, K.E. 1996. Douglas-fir beetle. USDA Forest Service Forest Insect and Disease Leaflet 5. 7 p.

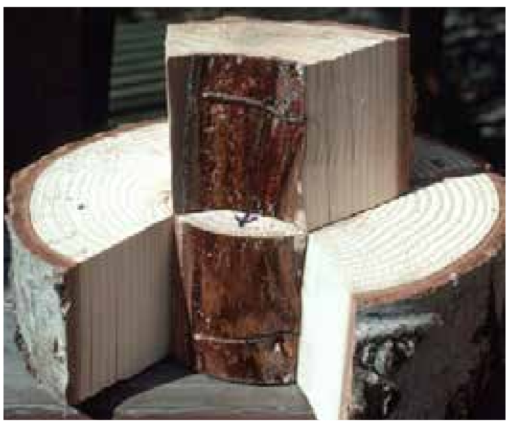
Fir Engraver (*Scolytus ventralis*)

Hosts: True firs

Distribution in California: Throughout the range of true fir.

Fir engraver beetle adult

Photo: Don Owen



Unsuccessful attack embedded in the wood

Photo: Don Owen

Fir engraver gallery

Photo: Sheri Smith

Fir mortality caused by the fir engraver beetle

Photo: Don Owen

Identification: The fir engraver is a medium-sized bark beetle, measuring about 4 mm in length. It is the largest of the shiny black *Scolytus* beetles and is recognized by the concave abdomen typical of the genus. Trees under attack are not always easily recognized, although sometimes boring dust will be evident on the bark. Often, successfully infested trees cannot be differentiated from uninfested trees until the year after attack when their foliage begins to fade. Extensive pitch streaming from entrance holes, and sunken patches of bark, indicate unsuccessful attacks. Trees eventually callous over unsuccessful attacks. These wounds become embedded in the wood and are marked by slightly swollen, rough areas of bark on the main stem. The adult or egg gallery of the fir engraver is oriented perpendicular to the grain of the wood and larval galleries are parallel to the grain on both sides of the egg gallery. Both the egg and larval galleries deeply score the sapwood.

Effects: All sizes of trees can be attacked and killed by the fir engraver. As opportunists, these beetles often kill trees affected by root diseases or stressed by other insects such as the Douglas-fir tussock moth. Sublethal attacks resulting in top-kill and branch flagging are common.

Ecological Role: The fir engraver is a key mortality agent for firs under stress. By killing trees, the fir engraver increases diversity in a stand and creates habitats for numerous organisms that depend on dead wood. Engravers also colonize down material and hasten its recycling by introducing wood decay fungi through the bark.

Life History: The fir engraver completes one generation per year in most locations. Two generations may be possible at lower latitudes and elevations. Adult beetles fly and initiate new attacks between June and September, with peak flight activity in July and August. Females initiate attacks and after mating, construct an egg gallery

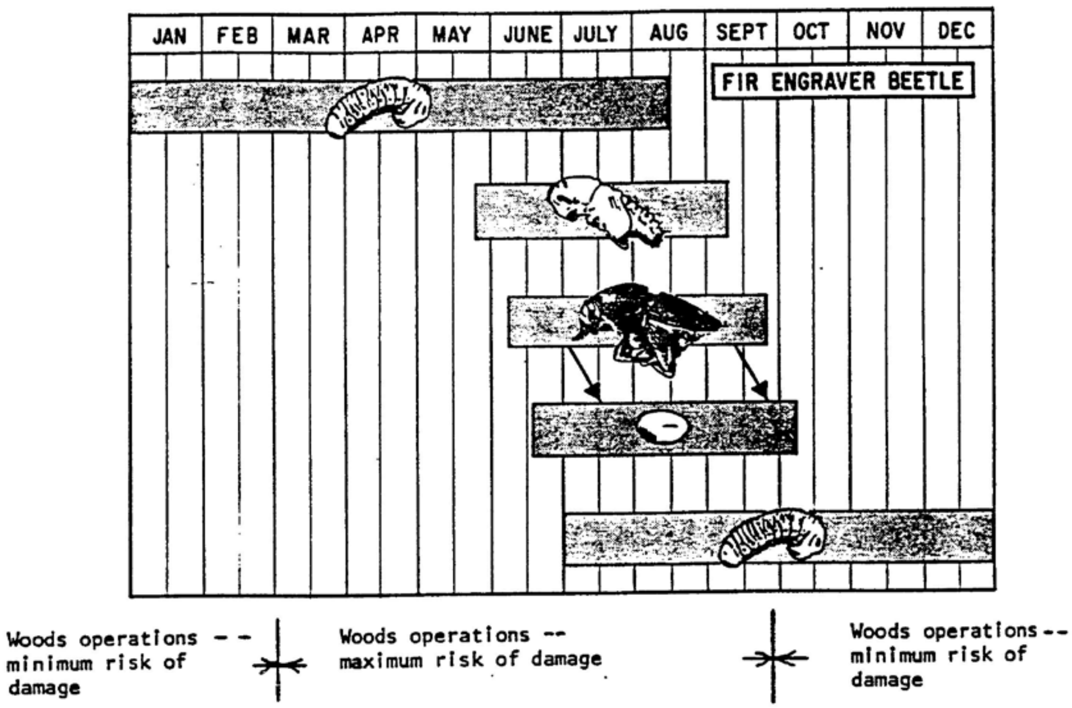


Figure 15. Life cycle of fir engraver beetle

perpendicular to the grain of the tree. Eggs are laid on both sides of this gallery, and larvae hatch within two weeks. Winter is passed in the late larval or pupal stage, and young adults mature by the following summer.

Conducive Habitats: Fir engraver activity is most commonly associated with trees infected by root pathogens. Other stress agents such as dwarf mistletoe, foliage diseases, and defoliating insects can predispose trees to engraver attacks. Typically, fir engraver populations will peak one or two years after a defoliator outbreak subsides. Drought conditions are perhaps the most significant trigger for creating substantial amounts of fir engraver habitat. By far the most impressive fir engraver outbreaks have occurred on dry fir sites (characterized by less than 30” of annual precipitation) during periods of drought. The fir engraver is also associated with windthrows and logging slash, but unlike the pine engraver, does not commonly build populations that can subsequently invade standing trees.

Similar Insects: Other engraver beetles attack red and white fir, including the silver fir beetle, *Pseudohylesinus sericeus*, and other species of *Scolytus*. They may be separated by gallery patterns, depth of sapwood scoring and characteristics of adult beetles.

Management Strategies: Since the majority of endemic fir engraver populations are associated with root diseases, management of these disease pockets will also serve to manage the fir engraver. Stand thinning measures for fir stands on drier sites generally do not seem to yield the same benefits that are seen with pines. However, thinning does typically result in increased growth and vigor and in wetter areas (areas with annual precipitation greater than 30 - 35”). Silvicultural practices aimed at maintaining healthy stand conditions appear to offer the best chance for minimizing engraver-caused mortality. Care should be taken during treatments to minimized tree injury and compaction as residual firs are easily damaged during harvest activities and are sensitive to soil compaction. These additional stresses can make them even more susceptible to fir engraver attacks. Large-scale outbreaks associated with drought conditions can best be managed by reducing the occurrence of fir on dry sites. Once an

outbreak begins, sanitation/salvage appears to result in little or no population reduction of fir engravers.

References

Cochran, P.H., 1998. Examples of mortality and reduced annual increments of white fir induced by drought, insects, and diseases at different stand densities. USDA Forest Service Research Note PNWRN-525.

Ferrell, George T. Risk-rating systems for mature red fir and white fir in northern California. Gen. Tech. Rep. PSW-39. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980. 29 p.

Ferrell, George T.; Hall, Ralph C. Weather and tree growth associated with white fir mortality caused by fir engraver and roundheaded fir borer. Res. Pap. PSW-109. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1975. 11 p.

Ferrell, G.T.; Otrosina, W.J.; DeMars, C.J., Jr. 1994. Predicting susceptibility of white fir during a drought-associated outbreak of the fir engraver, Scolytus ventralis, in California. *Can. J. For. Res*. 24:301-305.

Furniss, R.L., and Carolin, V.M. 1977. Western forest insects. USDA Forest Service Miscellaneous Publication 1339. 654 p.

Zhang, J.W., W.W. Oliver & M.W. Ritchie. 2007. Effect of stand densities on stand dynamics in white fir (Abies concolor) forests in northeast California, USA. Forest Ecology and Management 244:50-59.

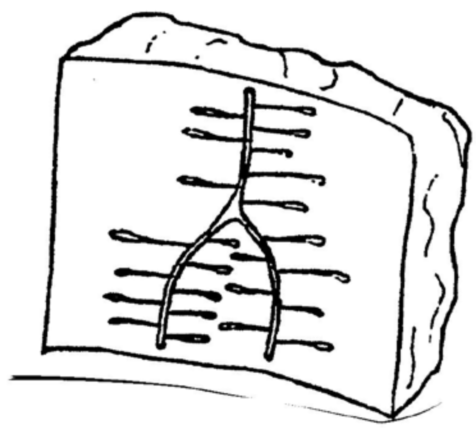
Pine Engraver Beetles (*Ips pini*, *I. latidens*, *I. paraconfusus*, *I. emarginatus, I. spinifer*, *I. mexicanus*, *I. confusus*)

Hosts: All species of pines; especially common on ponderosa, Jeffrey, lodgepole, sugar, and western white pines. Monterey, Bishop, gray, knobcone, Torrey and Coulter pines are also common hosts of pine engraver species.

Distribution in California: Throughout California in suitable hosts. The pinyon ips, *Ips confuses*, is restricted to the range of pinyon pines in California. The pine engraver beetle, *Ips pini*, is more common at higher elevations and on the east side of the Sierra Nevada and Cascade Mountains and in the southern California mountain ranges. The California five-spined ips, *Ips paraconfusus*, is more common west of the Sierra Nevada and Cascade Mountain crests and in the Coast Ranges.

Pine engraver adult

Photo: J.R. Baker and S.B. Bambara



Pine engraver gallery

Pine engraver galleries

Photo: Steve Munson

Identification: *Ips* beetles are recognized by the spines on the posterior ends of their elytra. Size of adults is variable, ranging from about 3mm in length for *I. pini* and *I. latidens* to 9mm in length for *I. emarginatus.* Since the males are polygamous, there may be several female galleries associated with each attacking male. These egg galleries extend from a main nuptial chamber located beneath the bark and are etched slightly into the wood. *Ips pini, I. latidens,* and *I. paraconfusus* typically colonize slash, small-diameter standing trees, and the tops of larger trees. *Ips emarginatus* is usually found in large ponderosa pines attacked by the western pine beetle and smaller pines infested by the mountain pine beetle. It also is found in Jeffrey pine associated with the Jeffrey pine beetle. Its galleries resemble those of the mountain pine beetle but are not packed with frass, and each contains a nuptial chamber. In standing trees, fading tops of large trees or whole crowns of small trees can be indicators of *Ips* infestation. Other external evidence consists of accumulations of boring dust in bark crevices and at the base of the tree. Pitch tubes can occasionally be found on the trunk (especially for the pinyon ips, *Ips confusus*). Characteristic egg galleries may be found under the bark, slightly engraving the sapwood, hence the common name engraver beetle. In slash, look for boring dust and galleries.

Effects: Most *Ips* beetles are associated with logging slash and windthrown material. On occasion, beetles can spread from this down material into standing trees and can cause significant tree mortality, especially in thickets and in young recently thinned stands. Tops of large trees may also be killed. *Ips emarginatus* attacks and occasionally aids in killing large trees, is considerably less common than other *Ips*, and is usually secondary to mountain, western or Jeffrey pine beetle. *Ips confusus* is the primary mortality agent for pinyon pine species in California.

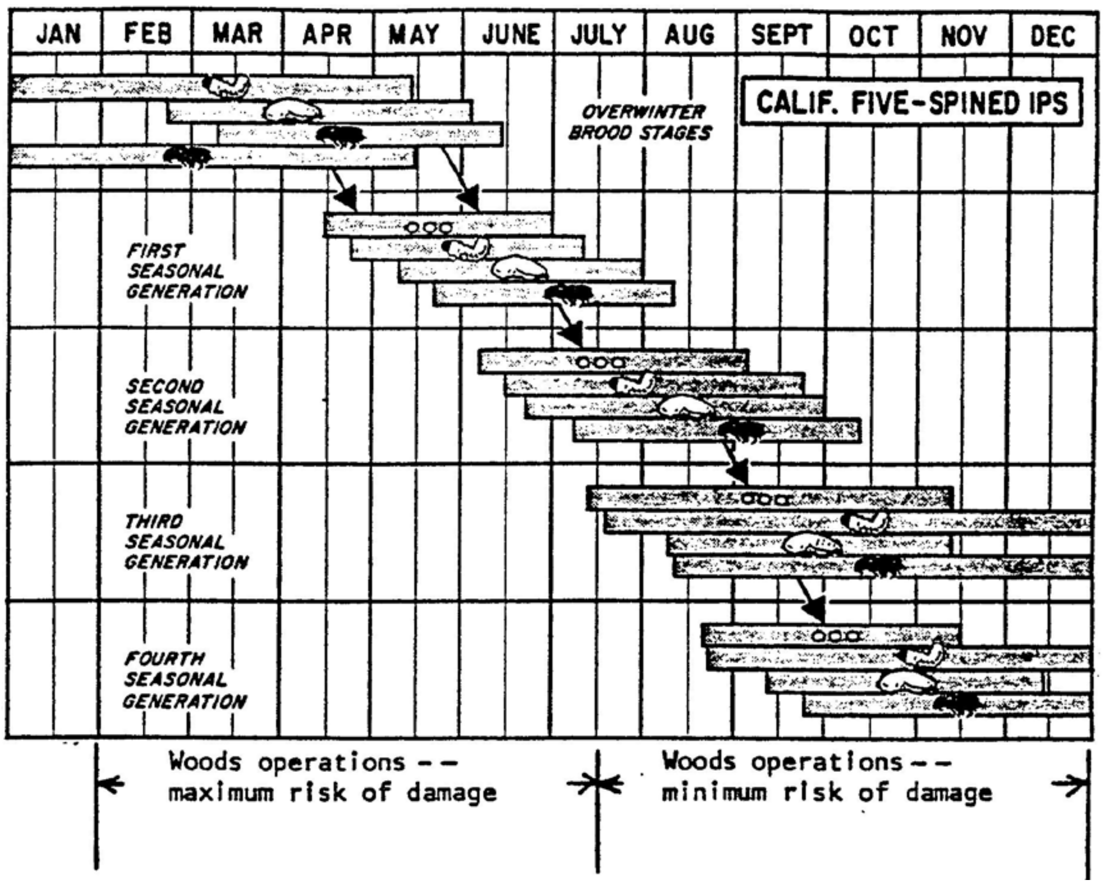
Damage caused by California fivespined ips

Photo: Don Owen

Ecological Role: *Ips* beetles help to accelerate the recycling of woody material by introducing wood decay fungi into host sapwood. Pine engravers also create gaps and introduce diversity into dense stands when they kill groups of young pines. As important causes of top-kill in large ponderosa pines, pine engraver attacks create special habitats for certain wildlife species.

Life History: *Ips* beetles can complete several generations in one year depending on the temperature and species. In California, adults typically emerge from their overwintering sites in late March to late April and fly in search of fresh slash or windthrown material. The males initiate attacks and produce attractants that draw other males and then females to the same host material. In the case of *I. pini*, males are joined by as many as four females. After mating in a nuptial chamber created beneath the bark by the male, each female constructs an individual egg gallery. Eggs are laid in these galleries, and larvae develop quickly. New adults are ready to emerge and fly in as few as 6 to 8 weeks. If the second or subsequent generations do not find fresh slash or windthrown material, they may attack standing trees. Some adults overwinter beneath the bark of their host while others emerge and fly off to hibernate in the forest duff. In southern California, there may be up to six *Ips* generations per year.

Figure 16. Life cycle of California five-spined ips



Conducive Habitats: Pine engravers are most commonly associated with stressed or wounded trees and down material, particularly of smaller diameters. Any activity or event that generates abundant amounts of slash or that stresses trees is likely to lead to elevated engraver populations. Slash produced from stand thinning activities between January and July is particularly conducive habitat for engravers, especially if the material is piled and not allowed to dry before beetle flights take place in the spring. These effects are most dramatic on the driest sites, and during abnormally dry years. In a year of "normal" precipitation, pine engravers are generally confined to down or severely stressed hosts and do not kill healthy trees.

Similar Insects: Ips egg galleries possess a nuptial chamber—an enlarged excavated area—with one to many galleries radiating from it. The egg galleries are free of frass. *Dendroctonus* galleries vary by species in shape but lack the nuptial chamber and are packed with frass. Ips adults display a pronounced concavity at the rear end of the elytra, which contains three to six spines on either side. This area on *Dendroctonus* adults is rounded with no spines. Frequently, both *Dendroctonus* and *Ips* species occur within the same tree with Ips species typically located in the top of the bole and *Dendroctonus* in the remainder.

Management Strategies: Management activities designed to minimize engraver populations are generally only necessary for the California five-spined ips, *Ips paraconfusus*, and to a lesser extent, the pine engraver beetle, *Ips pini*, on extremely dry pine sites and during drier-than-normal years. Under these conditions, the management of slash is critical. Thinning activities should be scheduled between the months of August and December. Slash generated between January and July provides the ideal habitat for Ips beetle reproduction, and this may lead to a large second generation that is capable of killing trees. If slash must be generated between January and July, it should be scattered and lopped or crushed in order to reduce its suitability as beetle habitat. An alternative approach is to generate enough additional fresh slash in mid-summer to absorb the emerging second generation and provide the beetles with an alternative to standing trees (called the "green chain" approach). Slash smaller than 7.5 cm (3 in) diameter is of little consequence in terms of brood production for *Ips*.

References

Dolph, R.E., Jr. 1965. Summary of Oregon pine ips damage in Pacific Northwest from 1952 to 1962 and suggested measures for and preventing *Ips* outbreaks in young ponderosa pine stands. USDA Forest Service, Pacific Northwest Region, Insect and Disease Control Branch, office report 31 p.

Furniss R. L. and J. B. Johnson. 2002. Field Guide to the Bark Beetles of Idaho and Adjacent Regions. University of Idaho. 125 p.

Kegley, S. J., R. L. Livingston, and K. E. Gibson. 1997. Pine engraver, Ips pini (Say), in the western United States. USDA Forest Service, Forest Insect and Disease Leaflet 122. 7 p.

Livingston, R.L. 1979. The pine engraver, *Ips pini* (Say), in Idaho. Life history, habits and management recommendations. Idaho Department of Lands, Forest Insect and Disease Control Report 79-3. 7 p.

Skelly, J. and J. Christopherson. Pinyon Pine: Management guidelines for common pests. University of Nevada Press.

Cedar Bark Beetles (*Phloeosinus* spp.)

Hosts: Coast redwood, giant sequoia, incense-cedar, Monterey cypress, Port Orford-cedar, and western juniper.

Distribution in California: Throughout the range of suitable host trees.

Boring dust produced by cedar bark beetles

Photo: Bill Ciesla

Identification: External evidence consists of twig killing (or flagging) or whole tree fading. This is usually accompanied by the presence of reddish brown boring dust in bark crevices. Egg galleries are simple and typically longitudinal, 2 to 7 cm long, and are often deeply etched into the wood. Egg niches are usually rather large and conspicuous. Larval galleries wander away from the parent galleries. Adults are reddish brown to black, shiny beetles ranging in size from 2 to 4 mm long.

Effects: Main effects on their hosts are twig killing or tree mortality; however, these insects are not aggressive and are generally found only attacking trunks, tops and limbs of weakened, dying or felled trees. They readily colonize broken branches and logging slash.

Life History: One to three generations are produced per year. Attacks occur in spring and summer. Newly emerged adults feed on the pith of twigs of living trees prior to constructing egg galleries under the bark. These twigs are often hollowed out completely causing them to die and partially break off and hang from the tree.

Similar Insects: This is the main bark beetle genus attacking redwood, cedar, cypress and juniper. There are some woodboring beetles that also attack these trees but they differ in appearance or feeding habits.

References

Furniss R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA Forest Service, Miscellaneous Publication No. 1339. 654 p.

Oak Bark Beetles: (*Psuedopityophthorus spp.)*

Hosts: primarily oaks and tanoak; also California laurel and buckeye, and potentially other hardwoods

Identification: Adults are tiny brown to nearly black beetles 1.2 - 2.6 mm long. Their bodies are cylindrical, roughly 3x as long as wide. As with other bark beetles, antennae are elbowed and clubbed. Larvae are tiny, cream-colored, legless grubs. Egg galleries are constructed in the cambial region and may or may not etch the wood. They are linear, free of frass and oriented perpendicular to the grain. Larval tunnels follow the grain, but may be difficult to see. A frothy exudate on the bark of live trees and/or boring dust on dead and dying trees are good signs of beetle attack. Tiny round exit holes are seen on the bark of the tree after the beetles complete their life cycle and leave the tree.

Light colored frothy exudate at beetle entrance holes on oak

Photo: Danny Cluck

Effects: Oak bark beetles colonize the main stem and branches of recently dead and dying oaks and other host species. They occasionally attack healthy trees when infested firewood or other infested host material is stacked next to live trees. Such attacks on live trees typically fail and are marked by the presence of a light-colored, frothy exudate at points where beetles bore into the bark. In contrast, attacks will succeed if a tree is severely stressed and unable to defend itself. Successful attacks are marked by the accumulation of light brown boring dust in bark crevices and around the base of the tree – a good sign that the tree is dying or already dead. Oak bark beetles and associated ambrosia beetles typically colonize oaks and tanoaks that are dying from sudden oak death.

Egg galleries of oak bark beetles

Photo: Don Owen

Insects

Life History: Male beetles individually tunnel through the bark to the sapwood surface. Two females typically join each male and extend the tunnel perpendicular to the grain of the wood, working in opposite directions and laying eggs in niches along the sides of the tunnel. The tunneling of these three beetles defines an individual egg gallery. Mass attack continues until galleries cover the surface of the wood. Larvae hatch from eggs laid in the galleries and mine through the cambial region / inner bark, following a path perpendicular to and away from the egg galleries. Larvae eventually pupate in the bark and emerge from trees as adult beetles. One life cycle develops in a tree or piece of host material. Adult beetle flight occurs in warm dry weather. In most areas of California, flight opportunities would occur from late winter or spring through fall. For a given locale, there are 2 or more generations per year, depending largely on temperature.

Similar Insects: Other bark beetles look similar, but none of these look-alikes infest the cambial region of oaks. Gallery pattern and location positively identifies the attacking beetle as a species of *Psuedopityophthorus.*

Management Strategies: Keeping trees healthy will prevent successful beetle attack. Attacks on a living tree indicate that the tree is either under stress or that infested wood is nearby. Do not stack freshly cut oak wood near to living oaks.

References

Dreistadt, SH. 1994. Pests of Landscape Trees and Shrubs: An Integrated Pest Management Guide. Univ. of Calif., Div. of Agric. and Nat. Res., Pub. 3359. 327p.

Furniss, RL and VM Carolin. 1977. Western Forest Insects. USDA Forest Service Misc. Pub. No. 1339. 654p.

Swiecki, TJ and EA Bernhardt. 2006. A Field Guide to Insects and Diseases of California Oaks. USDA Forest Service Gen. Tech. Rep. PSW-GTR-197. 151p.

Wood, SL. 1982. The Bark and Ambrosia Beetles of North and Central America (Coleoptera: Scolytidae), a Taxonomic Monograph. Great Basin Naturalist Memoirs No. 6, Brigham Young Univ. 1359p.

Twig Beetles (*Pityophthorus* spp., *Pityogenes* spp., *Pityokteines* spp.)

Hosts: Douglas fir, hemlock, pines, spruce, true firs and other conifers.

Distribution in California: Throughout the range of suitable hosts

Identification: Twig beetles typically colonize shade-weakened branches in the lower crown. Depending on the situation, twig beetles may also be associated with scattered twig and branch dieback in other parts of the crown. Tan sawdust is produced at attack sites. They also colonize cones, seedlings, saplings, fallen trees and trees killed by other bark beetles. On smaller twigs and branches, most of the cambium is mined beneath the bark. Small, star-shaped egg galleries generally occur under the bark of the larger branches and small trunks. Adult twig beetles are reddish brown to black and range from 1.5 to 3 mm long.

Single Branch Flagging. Warner Mountains, Modoc NF

Photo: Bill Woodruff

Twig beetle attacks caused branch flagging on this plantation pine, Antelope Mountain, Lassen NF

Photo: Danny Cluck

Effects: Attacks typically kill small twigs and branches of drought-stressed or otherwise weakened pines and other conifers. Although twig beetles are generally considered of secondary importance, under favorable conditions they may develop in sufficiently high numbers to attack and kill small trees. Some species of *Pityophthorus* impact cone crops in seed orchards and some have been implicated as the vectors of the pitch canker pathogen, *Fusarium circinatum*, in California, where they attack infected shoots and cones of Monterey pine.

Life History: Females excavate several egg galleries in the phloem and outer xylem. These galleries radiate from a nuptial chamber usually initiated by males. These galleries are found on larger branches more than 1 inch in diameter. On small branches the galleries are found in the pith and surrounding sapwood. One to many generations are produced each year, depending on species, elevation and latitude.

Similar Insects: See <u>*Ips*</u> discussion. Most twig beetles have elytral declivities and egg galleries that are somewhat similar to *Ips*; however, twig beetles are smaller in size and are typically found in branches and very small diameter trees.

Management Strategies: Insecticides are available to reduce losses of cone crops to *Pityophthorus orarius*.

References

Furniss R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA Forest Service, Miscellaneous Publication No. 1339. 654 p.

Hoover, K., D. L. Wood, A. J. Storer, J. W. Fox, and W. E. Bros. 1996. Transmission of the pitch canker fungus, *Fusarium circinatum* f. sp. *pini* to Monterey pine, *Pinus radiata*, by cone- and twig-infesting beetles. *The Canadian Entomologist* 128:981-94.

Rappaport, N. G., and D. L. Wood. 1994. *Pityophthorus orarius* Bright (Coleoptera: Scolytidae) in northern California Douglas-fir seed orchard: Effect of clone, tree vigor, and cone crop on rate of attack. *The Canadian Entomologist* 126:1111-18.

Pitch Moths

Pitch moths are in the Family Sesiidae (Order Lepidoptera). The adults resemble wasps and are characterized by having narrow wings that tend to be transparent and unscaled. Insects in this Family are also referred to as clearwing moths. Species in several genera bore in the roots, trunks, and branches of tree and shrubs. A few are considered pests in ornamental and plantation situations.

Sequoia Pitch Moth (*Synanthedon sequoiae*)

Hosts: Most California pines, including ponderosa, Jeffrey, lodgepole, Monterey, Bishop and sugar pine. Found also on ornamental pines such as Aleppo and Italian Stone. Occasionally found on Douglas-fir. Some ornamental pines such as Austrian pines and Aleppo pines are also susceptible.

Distribution in California: Throughout the range of suitable hosts.

Identification: The adults are black and yellow and resemble a wasp. Mature larvae are 25 to 30 mm long, yellowish white with a brown head capsule. Attacks on trees result in large singular pitch on the bole usually associated with branch nodes and junctions of limbs and bole. Brown to reddish brown frass pellets are incorporated in the pitch masses. Empty pupal skins are also typically found protruding from the pitch masses.

Sequoia pitch moth adult

Photo: Jed Dewey

Effects: Attacks are frequently associated with injuries at the junctions of the limbs and the bole. It is generally considered an ornamental pest but repeated attacks over several years can cause significant injury, particularly to young, small-diameter trees. Damage can include top and limb dieback or breakage. The sequoia pitch moth has been recorded attacking young ponderosa pines pruned to create or maintain fuel breaks. The resulting pitch masses are considered to be somewhat of a fire hazard if prescribed burning is used to maintain the break.

Pitch masses with empty pupal cases of sequoia pitch moths

Photo: Danny Cluck

Life History: Adults appear in mid-summer with peak emergence in June and July. Females lay eggs in bark crevices and in wounds on tree trunks and branches. Larvae bore into and feed in the cambium region causing copious pitch masses to form on the bole. Larvae pupate in a chamber that protrudes slightly from the pitch mass. The Sequoia pitch moth has a two year life cycle.

Similar Insects: Bark beetle pitch tubes are typically much smaller than those created by the Sequoia pitch moth.

Management Strategies: Controlling Sequoia pitch moth is only practical in urban settings. Removing the pitch masses, and making sure that the larvae are also removed or killed, from highly valued trees may help, but avoid skinning the tree. Pruning out the mass is not recommended, as the adults are attracted to open wounds. If pruning is necessary it should be done between October and January to allow wounds to heal before the next adult egg-laying period in the spring.

References

Furniss R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA Forest Service, Miscellaneous Publication No. 1339. 654 p.

UC Davis IPM: http://www.ipm.ucdavis.edu/

Wood Boring Insects

There are four families of insects that contain most of the economically important wood borers associated with western conifer forests: Cerambycidae (longhorned beetles), Buprestidae (flatheaded borers) and Scolytidae (ambrosia beetles) in the order Coleoptera and Siricidae (woodwasps or horntails) in the order Hymenoptera. Virtually all species in these families feed mainly on recently dead wood, and many have very broad host ranges. Wood borers are commonly found around timber harvest sites, burned areas, blowdown patches, and other locations where disturbances create a sudden abundance of weakened or dead trees.

Cerambycidae and Buprestidae feed in fresh cambial tissue during their early developmental stages and later move deeply into the wood. Ambrosia beetles (Scolytidae) confine their activity to the sapwood where they feed on symbiotic fungi. Woodwasp larvae feed on a symbiotic fungus that was injected during oviposition in the sapwood and heartwood.

The beetle families Cerambycidae and Buprestidae contain hundreds of species of diverse sizes and shapes. Most, however, are medium to large-sized insects, sometimes measuring over 3 cm in length in both the larval and adult stages. Although their feeding habitats are also variable, the majority of the species use wood from trees that have died within the previous year. There are far fewer species of wood wasps (12 species in the West), but many of them have several genera of trees within their host ranges. Most of the important western conifer ambrosia beetles belong to four genera, Trypodendron, Gnathotrichus, Monarthrum, and Xyleborus.

Common features of all wood borers (except the ambrosia beetles) include their strong association with wood decay fungi and their roles as recyclers of wood. They create long, meandering tunnels within their hosts and rapidly transform the wood into finer particles that are more readily decomposed by fungi.

Many wood borers have one-year life cycles and spend most of that time in the larval stage. The length of development time can be prolonged when borers feed primarily on a poor food source (e.g., sapwood and heartwood). Ambrosia beetles can complete several generations a year.

Flatheaded Borers (Buprestidae)

Hosts: All conifer and hardwood species

Distribution in California: Throughout the forested regions of California.


Buprestid adult

Photo: Johnny Dell


Flatheaded wood borer larva

Photo: Fabio Stergula


D-shaped exit hole of flatheaded wood borer

Photo: Fabio Stergula

Identification: The adults of many flatheaded borers are bright metallic colored beetles. They range in length from 8 to 40 mm (1/3 to 1 3/5 in), with many averaging around 20 mm (4/5 in). Larvae are long, cream-colored and legless. Many are shaped like horseshoe nails, with wide flattened segments toward their heads. Larval galleries can be found beneath the bark, usually etched well within the wood layer. These galleries are usually wide, meandering, and packed tightly with very fine boring dust which is quite distinctive from the coarser borings of the longhorned borers (Cerambycidae). For many species, larvae complete their development in the sapwood and sometimes the heartwood. Emerging adults make exit holes in the wood and bark that are flattened or oval in cross section.

Effects: A few species of flatheaded borers attack and kill apparently healthy trees; most attack weakened, fire-injured, dead and recently felled trees. Some species are attracted to smoke from forest fires. Galleries in the wood can affect product value. The California flatheaded borer, Phaenops californica, has been attributed to pine mortality in southern California.

Ecological Role: The primary function of flatheaded woodborers is that of nutrient cycling. These insects accelerate the rate of decomposition of dead wood by providing avenues of access for fungi and by reducing the wood they feed on to smaller particles that are more readily decomposed. Flatheaded borer attacks on standing trees are often in concert with other insects, such as bark beetles, and root disease. During drought periods, some species contribute to gap formation as they kill trees in dense stands or on harsh sites.

Life History: Most species have a one-year life cycle with adults occurring in the spring or summer. Females select a suitable host and lay eggs in bark crevices or underneath bark scales. The larval stage usually feeds in the phloem/cambium layer for a short time before burrowing into the wood. The winter is usually spent in the larval stage although some larvae may pupate in the fall and pass the winter as adults. Once adults emerge from their hosts, they feed on pollen or on foliage in order to reach sexual maturity. Some species have much longer life cycles and spend several years in the larval stage, often due to feeding on poor nutrient host material.

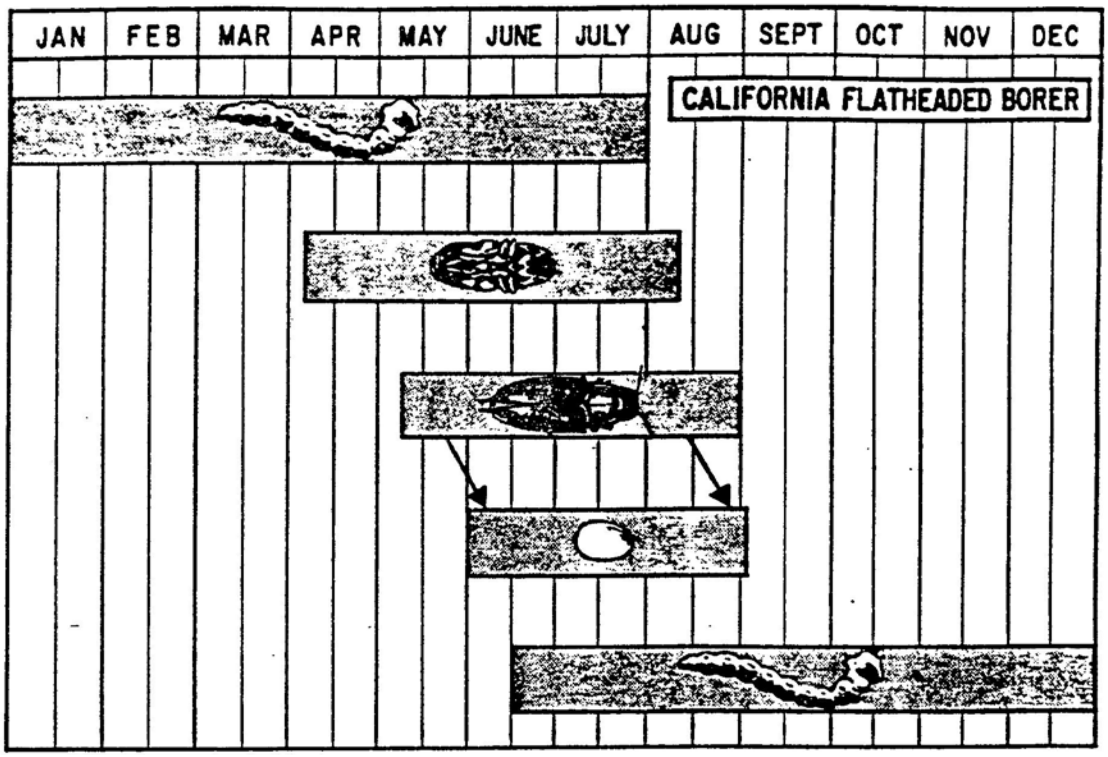


Figure 17. Life cycle of the flat-headed borer

Conducive Habitats: Most flatheaded borers depend on wood from recently dead or heavily stressed trees. Therefore, they are commonly associated with trees damaged by fire, windthrow, bark beetles, and other insects or diseases. Many species infest logging residues as well. In extreme instances, some species of *Phaenops* will attack and kill live trees under severe moisture stress. The flatheaded fir borer (*P. drummondii*) is a primary killer of Douglas-fir on dry sites in southwestern Oregon and Northwest California.

Management Strategies: Since flatheaded borers are generally associated with dead or severely damaged trees, they are usually not the object of direct management activities. As with roundheaded borers, potential damage to wood products can be minimized by the prompt utilization of dead or recently felled trees. Management for the California flatheaded borer in southern California is similar to that for bark beetles in that it is generally aimed at reducing stocking levels or otherwise alleviating stress on host trees.

References

Furniss, R.L., and Carolin, V.M. 1977. Western forest insects. USDA Forest Service Miscellaneous Publication 1339. 654 p.

Longhorned Borers (Cerambycidae)

Hosts: All conifer and hardwood species

Distribution in California: Throughout the forested regions of California.

Roundheaded borer

Photo: Bill Ciesla

Identification: Most longhorned borers are fairly large beetles, measuring from 1 to 5 cm (0.4 to 2.0 in) in length. Longhorned borers commonly have antennae that are at least half the length or greater than the adult body. Larvae are fleshy, cream-colored, grubs with darkly colored mandibles. Many of the western longhorned beetles feed in the cambial layer of their hosts before tunneling into the wood. The larval galleries beneath the bark are generally very broad and meandering. The galleries are packed loosely with boring material that is usually very coarse when compared to the boring dust of bark beetles or flat-headed borers (Buprestidae). As newly developed adults emerge from the wood, they leave more or less round exit holes that can be from 5 to 15 mm (0.2 to 0.6 in) in width depending on the size of the beetle.

Roundedheaded borer emergence hole

Photo: Minnesota Department of Natural Resources

Effects: The vast majority of western longhorned borers infest the wood of recently dead trees. Very few are involved in the actual death of the trees. They introduce wood decay fungi into the wood and hasten the rate of decay. Their tunnels can lead to a significant loss in value of logs to be processed for lumber. The roundheaded fir borer, *Tetropium abietis*, is commonly involved in mortality of drought-stressed firs in California.

Ecological Role: Longhorned wood borers are significantly involved in nutrient cycling. Larval feeding reduces wood to smaller particles that are more easily colonized by fungi. The borers make the interior of a tree more accessible to decay fungi, some of which are introduced into the host by the insects as eggs are laid in the bark. Developing larvae, sometimes numbering in the thousands within a single tree, serve as food sources for other insects and for birds and small mammals.

Life History: This group contains a very large number of species, many of which have several conifer and hardwood genera as hosts. As a consequence, it is difficult to generalize life cycles. The adults of most longhorned beetles appear sometime in the summer as they fly in search of suitable host material. Female beetles generally lay their eggs beneath bark scales or in conical egg niches chewed in the bark. Larvae develop during the summer and fall, often spending their first two or three weeks in the phloem/cambium layer before tunneling into the wood. They overwinter in the larval stage and resume feeding inside the wood until completing their development sometime in the summer. As larvae approach maturity, they burrow toward the surface of the wood and excavate pupal chambers in which the pupae and adults finish their development. Most roundheaded borers complete their life cycles in one year although some require several years. The life cycles of many species are not well known.

Conducive Habitats: Most cerambycids require recently dead trees for their development. Thus, they are commonly found around harvesting sites, areas of windthrow, root disease centers, and around burned areas. Cerambycids often colonize trees infested by bark beetles, sometimes obliterating the bark beetle galleries with their own.

Management Strategies: The only management activity that is directly aimed at reducing the effects of roundheaded borers is the timely processing of wood intended for lumber or other high-quality wood products. If trees remain in the woods for any length of time after they die, they will be effectively colonized by various species of wood borers and wood value will be reduced.

References

Furniss, R.L., and Carolin, V.M. 1977. Western forest insects. USDA Forest Service Miscellaneous Publication 1339. 654 p.

Horntails or Woodwasps (Siricidae)

Hosts: All California conifer species

Distribution in California: Throughout the forested regions of California.

Adult horntail

Photo: Ed Holsten

Horntail gallery

Photo: Ed Holsten

Identification: These thick-waisted wasps are fairly large, measuring from 20 to 35 mm (0.8 to 1.4 in) in length. Size is quite variable, even within species. Wood wasps are also called "horntails" due to a short horn-like processe at the posterior end of the abdomen. Females also have prominent ovipositors that extend straight back when not in use. The adults are sometimes metallic blue, black, or reddish brown in color. Larvae are cylindrical, yellowish-white, and each has a small spine at its posterior end. When adult wasps emerge from their hosts, they leave perfectly round exit holes in the wood.

Effects: The horntails are associated almost exclusively with recently dead trees. They are important agents in the recycling of nutrients, as the larvae consume wood and make it more easily decomposed by fungi.

Life History: The biology of woodwasps is known only in general terms. The adult stage is commonly seen in the summer, when wasps are flying in search of freshly dead host material. Upon finding a host, the female inserts her long ovipositor deep into the wood and lays eggs. These are deposited together with a symbiotic fungus that breaks down the wood and serves as a food source for the developing larvae. Unlike wood-boring beetles, wood wasps do their entire feeding within the wood and do not feed in the phloem/cambium layer. Larvae feed for one to three years within the wood, packing their galleries with fine boring dust. They later construct pupal cells near the surface of the wood, where they transform into adults. The females lay their eggs through the ovipositor, which is thrust into the bark for distances up to an inch. At times the insect is unable to remove the ovipositor from the bark and the living or dead bodies are sometimes found fastened on the trunks of trees.

Adults are attracted to freshly felled timber and trees that have been scorched by fire. Females have been observed ovipositing in scorched logs that are too warm to keep one's hand on. These wasps seem to be attracted to smoke and can be so numerous that they become a nuisance to firefighters.

Conducive Habitats: Most of the western siricid species have very broad host ranges covering several genera of conifers and hardwoods. Most rely entirely on recently dead wood and thus, are commonly seen around harvesting sites where they invade slash and stumps, around burned areas, and in other settings where recently dead trees can be found.

Management Strategies: The only management practice directed at these insects is the prompt utilization of material harvested for wood products. Kiln drying of lumber will eliminate those larvae that remain in the wood after lumber has been cut.

References

Furniss, R.L., and Carolin, V.M. 1977. Western forest insects. USDA Forest Service Miscellaneous Publication 1339. 654 p.

Ambrosia Beetles (*Trypodendron lineatum*; *Gnathotrichus* spp.; *Platypus wilsoni*)

Hosts: Virtually all species of conifers and some hardwoods such as aspen, poplar, oak and maple.

Distribution in California: Throughout the forested regions of California.

Trypodendron lineatum adult

Photo: Petr Kapitola

White boring dust produced by *Trypodendron lineatum*

Photo: Daniel Adam

Trypodendron lineatum galleries

Photo: Andrea Battisti

Identification: The adults are small, darkly colored beetles measuring from 3 to 5 mm (0.1 to 0.2 in) in length. Adults bore directly into the sapwood of their hosts, each producing a pile of fine white boring dust at the point of entry. As they construct their galleries, the beetles introduce a fungus that grows inside the gallery and in the adjacent wood. The black stain produced by this fungus around the insect's gallery is a good diagnostic tool for recognizing infestation by ambrosia beetles. Ambrosia beetles galleries are commonly multi-branched galleries that may possess egg niches, or cradles, below and above the parent gallery.

Effects: Weakened, dying, recently cut or dead trees are attacked. Galleries cause defect in logs. Some species can attack freshly cut lumber before it has been dried. Populations can build up in windthrown and fire-killed trees, bases of trees attacked by bark beetles, logging slash, and logs in storage. These beetles are unique among bark beetles in that larvae feed upon a special type of fungus, known as the ambrosia fungus, which grows in the galleries. Larvae do not feed on wood or phloem as in other bark beetles.

These insects are known as the ambrosia beetles because of their habit of propagating certain fungi called ambrosia that is eaten by both adults and larvae. The adult beetles carry in the fungus spores, prepare beds for them, and tend the gardens, which are fertilized by larval excrement. Each species has its own special variety of fungus. There must be a certain amount of moisture present in the wood or the fungus will not grow. Each colony will continue in a given host as long as conditions are right for the growth of their fungus, but will abandon a tree as soon as it begins to dry out. Trees attacked by these beetles are typically dead, dying or have sustained severe fire injury to cambial tissue and the sapwood surface is in a fermenting condition.

In the western U.S., ambrosia beetles are not considered tree killers. Their most important effects are as agents of degrade. Lumber or veneer cut from ambrosia beetle-infested wood is devalued substantially, depending on the intensity of infestation and on the category of the wood product.

Life History: Ambrosia beetles fly early in the spring (March-May) in search of suitable host material. In the case of *Trypodendron,* the host selection is done by the female whereas with

Gnathotrichus, the males initiate the attack. Parent beetles excavate tunnels directly into the sapwood of the host and the females lay eggs in shallow niches on the sides of the tunnel wall. Once the eggs hatch, the developing larvae enlarge these niches, but actually feed on the fungus growing in the gallery. Development is rapid, requiring only 6-10 weeks from the egg stage to the new adults. *Trypodendron* beetles emerge from the host in July and August and hibernate in forest duff or litter, while *Gnathotrichus* broods remain inside the host for the winter and emerge in the following spring. *Platypus wilsoni* is a less common species of ambrosia beetle; it is more elongated and cylindrically shaped than the scolytid ambrosia beetles. Many of its habits are similar to the scolytid ambrosia beetles, with the difference that the platypodids can penetrate deeply into the heartwood.

Conducive Habitats: Ambrosia beetles are much more common west of the Cascades and Sierras than on the drier East Side. Throughout their range they prefer windthrows, logging slash, stumps, and recently dead trees that have not been heavily colonized by bark beetles. Since ambrosia beetles derive their nourishment from the symbiotic fungus growing in their galleries, the proper moisture content of their host material is critical. *Trypodendron,* the more common genus, prefers material that was felled in the previous fall and winter. *Gnathotrichus* will infest fresher logs and actually prefers material felled one to two weeks previously. Ambrosia beetles will sometimes be found in a standing tree, but only if the tree has recently died from some other cause.

Similar Insects: May be confused with other bark beetles; however, ambrosia beetles are the only ones that bore straight into the bole producing fine, white boring dust.

Management Strategies: The primary management emphasis with ambrosia beetles concerns avoiding degrade of wood products that results from their gallery construction. At the logging site, it is important to minimize the amount of susceptible material on the ground during the flight period of the ambrosia beetles. Some direct controls are also available, including the use of trap logs and synthetic pheromones applied in "trap out" programs. High-value logs decks are sometimes protected by water-misting or pesticides applied to prevent attacks.

References

Furniss, R.L., and Carolin, V.M. 1977.
Western forest insects. USDA Forest Service Miscellaneous Publication 1339. 654 p.

Nijholt, W.W. 1978. Ambrosia beetle. A menace to the forest industry. Canadian Forestry Service, Pacific Forest Research Centre. Report BC-P-25. 8 p.

Defoliating Insects

Defoliating insects are exceeded only by bark beetles in importance as forest insect pests. The larvae feed on and in the needles of conifers and leaves of broadleaf trees, thus depriving the trees of the ability to photosynthesize. In some cases, an entire tree may be defoliated in a short period of time, eventually dying. Less severe defoliation can damage tops, branches, twigs, buds, or cones. Growth, both in height and diameter, may also be reduced due to injury. Affected trees may become susceptible to bark beetle attack or attack from other destructive pests.

Most of the forest defoliators are in the Orders Lepidoptera (butterflies, moths, loopers, case bearers, needle miners) and Hymenoptera (sawflies). Some species may cause localized outbreaks that last for a year or two, while others may cause extensive outbreaks of a over a decade or longer.

Characteristics: Adult insects in the order Lepidoptera have two pair of functional wings (Douglas-fir tussock moth females have only tiny rudimentary wings) that are covered with scales; the forewings are larger than the hind wings. The venation of the wings may be used to separate families and occasionally species. In most species, the mouthparts are modified into a characteristic long, flexible proboscis.

The larvae are well-known and readily recognized by most people ("caterpillars"). They are generally characterized (with few exceptions) by having three pairs of jointed legs on the first three segments behind the head and three to five pairs of short, fleshy, unjointed prolegs on the abdominal segments. Larvae have chewing mouthparts.

The order Lepidoptera is typically divided into two groups: moths and butterflies. They may be easily separated in the mature stage by the following characteristics:

1. Moths: Antennae of various forms, but never with a knobbed tip. Most are night or twilight fliers. Wings usually folded along abdomen or spread horizontally when at rest. The pupa is often enclosed in a silken cocoon.
2. Butterflies: Antennae slender for most of its length, with the tip dilated to form a knob. Most are day fliers. Wings are held vertical when at rest. Pupa is exposed, never enclosed within a cocoon.

Left: Luna moth, showing feather-like antennae

Photo: Ronald Billings

Right: Painted lady butterfly, showing knobbed tipped antennae

Photo: David Cappaert

Detection Methods: Outbreaks of forest defoliators are generally first detected during aerial surveys and on the ground. By the time the epidemics are underway damage is occurring. Other detection methods include the establishment of monitoring plots in susceptible stands.

These monitoring plots may consist of “beating plots” where the lower branches of selected trees are beaten with a stick or shaken to dislodge insects. The insects fall onto a cloth, are collected, counted and identified. Through yearly monitoring, any increase in numbers may be noted, predictions made, and control measures taken before significant damage occurs.

Pheromones (sex attractants) have been developed for the Douglas-fir tussock moth and budworms as well as non-natives such as Gypsy moth. Traps are baited with pheromones to capture the males searching for females. As in the case of the “beating plots” the objective is to detect changes in populations and make predictions before significant damage occurs.

Evaluation Methods: When significant populations or damage is detected, evaluation surveys are made of the eggs or larvae. Larval populations per given unit of foliage can thus be estimated after analyzing various factors such as number of eggs, egg viability, parasitism, etc.

Management Strategies: Endemic defoliator populations are usually kept at low levels by a combination of predators, parasites, climatic factors, or host foliage characteristics. However under certain conditions, these controlling factors lose their capacity to regulate population levels. Because of their enormous reproductive potential, defoliator populations can increase dramatically in fairly short periods. Outbreak populations ultimately collapse due to climatic factors and/or natural enemies, i.e. diseases (viral, bacterial, or fungal), parasites and predators.

Direct suppression of defoliators by applying insecticides from the air, has been the most widespread, successful and even controversial of forest insect treatment options. The insecticides include conventional chemical compounds, viruses, bacteria, pheromones, juvenile hormones or feeding deterrents. Biological control, using insect parasites against pest organisms, can be effective in regulating certain populations. Entomologists have tried establishing foreign parasites in the case of introduced defoliators such as the larch case bearer. Stand management practices may have some effect upon defoliator populations, but perhaps more importantly, will influence how well a stand survives the impact of defoliation.

Table 12. Common California Forest Defoliators

COMMON CALIFORNIA FOREST DEFOLIATORS

Name	Hosts	Tree Size	Damage	Field I.D.	Prevent/Control	Notes
Western Spruce Budworm *Choristoneura occidentalis*	Douglas-fir, true firs	All sizes and classes	Mine buds; web needles into feeding shelter. Damaged needles retained on branch tips in loose web giving tree a brownish appearance. Feed on staminate flowers.	Large larvae with brown head and body, prominent ivory spots, pupae yellow-brown w/amber brown case	Parasites, predators, adverse weather, stand management	Not common in California. Pupae found among webbed needles
Modoc Budworm *Choristoneura viridis*	White fir	See above	See above	Mature larvae green w/ light-yellow or pale buff head. Pupae green w/light grayish transparent case	See above	Sporadic outbreaks, locally important. Change in name pending. Pupae found among webbed needles
Sugar Pine Tortrix *Choristoneura lambertiana*	Lodgepole, sugar and ponderosa pines	See above	See above	Different host. Larvae rust color w/reddish tan head, pupal case amber colored	See above	Sporadic outbreaks; no great damage. Presently a taxonomic complex. Pupae found among webbed needles

COMMON CALIFORNIA FOREST DEFOLIATORS (continued)

Name	Hosts	Tree	Damage	Field I.D.	Prevent/Control
Western Tent Caterpillar *Malacosoma californicum*	Wide range of hardwood trees and shrubs	See above	When abundant, strip foliage from trees and shrubs over wide area	Silken tents, clusters of hairy caterpillars* near or in tent	Parasites, predators, NPV
Douglas-fir Tussock Moth *Orgyia pseudotsugata*	White fir and inland Douglas-fir	All sizes and classes	Initially new foliage, then older	Hairy cocoons and egg masses, colorful and hairy larvae*	Pheromones for monitoring, NPV, Bt, Sevin-4-oil
Pine Sawflies *Neodiprion* sp.	Ponderosa, Jeffrey, Pinyon, and Monterey pine	Common in young growth, open grown stands	Clip old and new foliage	Naked caterpillars, green to brownish, >5 pair prolegs	Silvicultural, parasites, NPV, predators
White-fir sawfly *Neodiprion abietis*	White fir	More common in dense 2nd growth	Old foliage only	See above	See above
Silverspotted Tiger Moth *Halisidota argentata*	Douglas-fir, white fir, lodgepole pine, western hemlock, Monterey pine, others	Apparently all sizes	Prefer previous years' growth, do not attack buds	Fall: in colonies; Spring: large hairy red-brown, yellow and black caterpillars	Generally regarded as not economically important
White-fir Needleminer *Epinotia meritana*	Red fir (primary), white fir (secondary)	Overmature, mature, understory	Branch killing, Deterioration of tree crown, susceptibility to Scolytus beetles	Needle mining, discoloration; WF: needles tied by silk	Parasites

Douglas-fir Tussock Moth (*Orgyia pseudotsugae*)

Hosts: White fir is the principal host in California. Douglas-fir, grand fir and white fir are principal hosts in other parts of western North America.

Distribution in California: In California, DFTM outbreaks have primarily occurred on ridge tops, upper slopes, and in mixed conifer stands which have a heavy ingrowth of white fir.

A defoliated white fir, the preferred host of Douglas-fir tussock moth, stands next to a red fir, a non-host.

Photo: Don Owen

Visible defoliation during second year of Douglas-fir tussock moth outbreak

Photo: Dave Schultz

Identification: The Douglas-fir tussock moth has a characteristic pattern of defoliation. First, tree tops and outermost portions of branches are defoliated. Damage progresses to the lower crowns and innermost portions of the branches. Fine silken webbing can often be seen in the tops of infested trees. Brown branch tips, bare twigs, and damaged needles give a heavily defoliated stand a brown, dead appearance.

Each of the 5 to 7 larval stages (instars) is covered with long hairs. Newly hatched larvae are about 3 to 6 mm (1/8 to 1/4 in) long, have dark bodies, and are covered by long, fine, light-colored, body hairs. Larvae in subsequent instars have two long, dark, horn-like tufts of hair projecting forward above their heads, and a single dark tuft projecting backward on their posteriors. Full-grown larvae are about 3.2 cm (1 1/4 in) long. Toward the front, along the middle of their backs, are four shorter, buff-colored tufts. The rest of their bodies are covered with short hairs radiating from red, button-like spots.

Pupation takes place inside grayish brown, spindle-shaped cocoons made of shed larval hairs. Cocoons normally are located on the foliage, branches, and boles of host trees and are quite cryptic. During outbreaks, they may also occur on non-host plants or on the ground.

Adult males are small grayish brown moths with feathery antennae and wingspans of about 25 to 34 mm (1 to 1 1/3 in). Males typically fly in the afternoon. Adult females are flightless, with tiny rudimentary wings and large, grayish abdomens with darker tips. They lay their eggs on or near their old cocoons in masses of frothy gelatinous material mixed with hair from the female's abdomen. The grayish egg masses remain on the trees throughout the winter.

Effects: Outbreaks appear to be synchronized over large geographic areas, perhaps influenced by large-scale weather patterns. Intervals between outbreaks are usually 8 to 9 years, and outbreak duration is 2 to 4 years. Outbreak collapse is often caused by a virus specific to the Douglas-fir tussock moth in combination with other mortality factors, such as predators and parasites.

Eggs hatch in late spring, and newly hatched larvae feed only on new foliage growth, causing it to shrivel and turn brown. After new needles have been consumed, the older larvae feed on old foliage. Larvae generally pupate by early August, and adults emerge, mate, and lay eggs from August through October.

Ecological Role: The Douglas-fir tussock moth is a primary regulator of foliage biomass and effectively redistributes nutrients contained in the forest canopy to the ground. In mixed conifer stands, it functions as a thinning agent that favors the growth of non-host species, such as pines, by causing selective mortality of host trees.

Severe outbreaks can cause significant mortality and top-kill of both overstory and understory trees relatively quickly (1 or 2 years). Bark beetle attacks can occur on the most severely defoliated (>90%) trees.

Life History: The Douglas-fir tussock moth produces one generation per year. Adults appear from August through October. Male flight activity is apparently stimulated by light and increasing temperature. It begins about midday, peaks in late afternoon, and rapidly diminishes at dusk.

Females do not fly, but rather cling to the pupal cocoon and emit a sex pheromone that attracts males. They remain on the outside of the cocoon and lay eggs immediately after mating.

Each female lays her eggs in a single mass, which may consist of only few or as many as 300 spherical, white eggs. After egg laying is complete, the female dies, leaving the eggs to overwinter in the gray, hairy mass attached to the cocoon.

Egg hatch in spring coincides with bud burst and shoot elongation of the host trees. One to seven days after the eggs hatch, the tiny, hairy caterpillars crawl to new needle growth and begin feeding on the underside of new needles. As the larvae grow, they eventually consume both new and old foliage. Larval growth is slow at first, but becomes progressively faster as larvae pass through growth stages and eat proportionately more.

Since female moths do not fly, major population dispersal is by windborne newly-hatched larvae. When the larvae drop off foliage, they produce long silk threads that allow them to be carried by

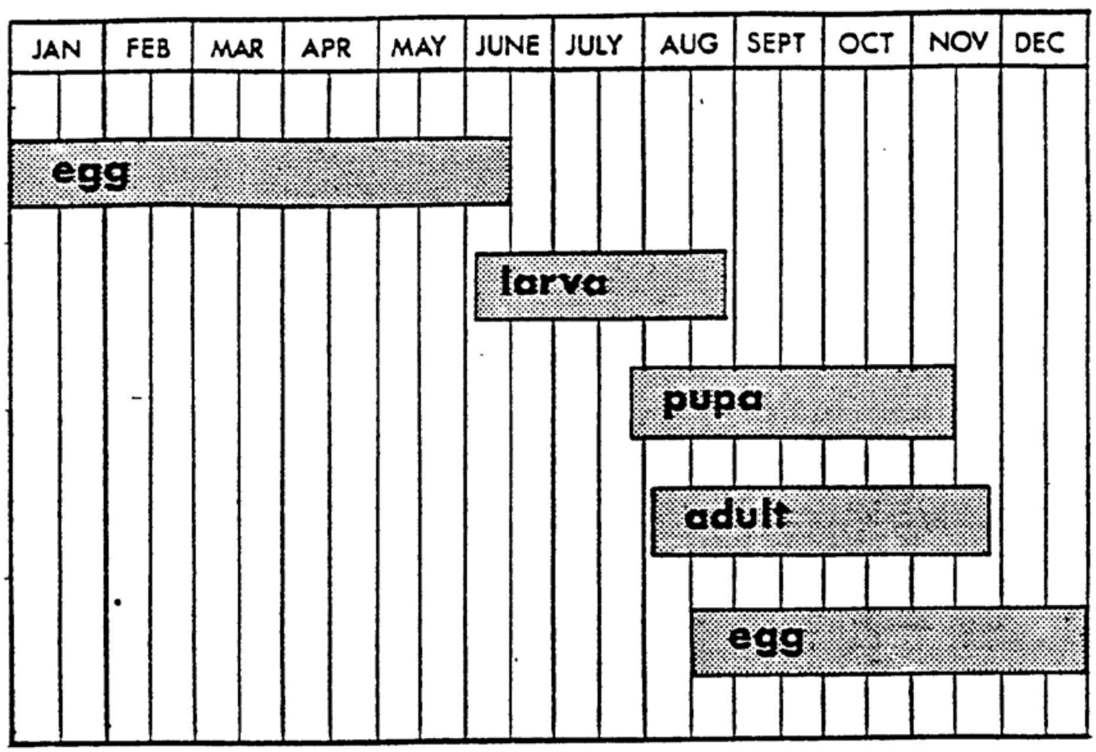


Figure 18. Life cycle of the Douglas-fir Tussock Moth

Douglas-fir tussock moth egg mass and cocoon on white fir

Photo: Don Owen

air currents. The distance most caterpillars travel, however, rarely exceeds 500 m (0.25 mi).

Most larvae pupate in July, with some carry over into August. Pupation takes place inside grayish tan, spindle-shaped cocoons made of larval body hairs. Cocoons normally are located on the foliage, branches and boles of host trees and can be quite difficult to find when populations are low. During outbreaks, they may also occur on non-host plants or on the ground. The pupal stage lasts from 10 to 18 days, depending on temperature. From August through the fall, moths emerge to begin the life cycle again.

Conducive Habitats: The probability of defoliation is highest in stands that are composed primarily of host species, occur on drier sites, and have high tree densities and high proportions of trees with large crown diameters.

Similar Insects: Early damage and webbing in trees may be similar to that caused by western spruce budworm; however, the larvae are very distinct. Top kill may be confused with damage by bark beetles, but needles will still be intact with beetle injury.

Management Strategies: Thinning for the dual purpose of lowering stocking density and reducing percentage of host species to less than 30 percent of the stand may help to decrease the effects of defoliation. Annual pheromone trap surveys are conducted by state and federal cooperators across California for the purpose of early outbreak detection. Suppression treatments using microbial insecticides such as *B.t.* or nuclear polyhedrosis virus may be desirable and feasible in well-defined high-value areas where heavy damage is expected.

The Douglas-fir tussock moth has a number of natural enemies, including parasites, predators and pathogens. These enemies, along with environmental factors, usually keep populations at low levels.

Management recommendations to prevent tree damage from tussock moth outbreaks involve four major activities: early detection, evaluation, suppression, and prevention. These activities must be well integrated to insure adequate protection from the pest.

To prevent damage caused by the tussock moth, populations need to be detected early and controlled before severe defoliation occurs. Population trends can be determined by annual monitoring of adult males, egg masses or larvae. Adult numbers are evaluated by attracting flying males to sticky traps with a sex pheromone. Systematic sampling of egg masses in the late fall will provide an estimate of the following year's population. The number of larvae in the population can be estimated by sampling foliage in the lower crown of host trees. If insect numbers are increasing, this can be detected prior to an outbreak and suppression, if needed, can be initiated before significant damage to trees occurs.

The need to suppress a tussock moth population depends on the impact it is expected to have on forest resources. Decisions for control must be based on a thorough evaluation of the potential of the insect population and the resource values at stake. Models of insect population behavior, stand dynamics, and economic variables are available for use in integrated pest management systems.

There is some indication that white fir growing on sites best suited for pine and other warm, dry sites are most susceptible to Douglas-fir tussock moth. Where offsite fir is well established and conversion to proper tree species would be uneconomical, some form of annual tussock moth population monitoring should be considered to detect increases in insect numbers. The preferred way to keep losses low is to work toward healthy, thrifty stands, growing on suitable sites. Thinning for the dual purpose of lowering stocking density and reducing percentage of host species to less than 30 percent of the stand may help to decrease effects of defoliation. Annual pheromone trap surveys are conducted by state and federal cooperators for the purpose of early outbreak detection.

Three materials are registered and available that can be used to reduce outbreak population numbers. Carbaryl is the only chemical pesticide presently registered for aerial application against Douglas-fir tussock moth. A bacteria that is effective against lepidopterans, *Bacillus thuringiensis*, and a nuclear polyhedrosis virus specific to Douglas-fir tussock moth have both been developed into biopesticides that are used against the Douglas-fir tussock moth. Neither of these biopesticides is hazardous to most insects, birds, mammals, or aquatic systems; however *B.t.* will affect non-target lepidopterans, while the inert ingredients in the virus product have caused skin irritations to people and mammals. If control is necessary, a State or Federal pest control specialist should be consulted for current recommendations.

Suppression treatments using microbial insecticides such as *B.t.* or nuclear polyhedrosis virus may be desirable and feasible in well-defined high-value areas where heavy damage is expected.

References

Beckwith, R.C. 1978. Larval instars of the Douglas-fir tussock moth. Agriculture Handbook No. 536. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Combined Forest Pest Research and Development Program. 15 p.

Brookes, M.H., R.W. Stark, and R.W. Campbell (editors). 1978. Douglas-fir tussock moth: a synthesis. Tech. Bull. 1585. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Science and Education Agency. 331 p.

Coleman, T., M.I. Jones, B.Courtial, A.D. Graves, M. Woods,A.Roques, and S.J. Seybold 2014. Impact of the first recorded outbreak of the Douglas-fir tussock moth *Orgyia pseudotsugata*, in southern California and the extent of its distribution in the Pacific southwest region. Forest Ecology and Management, Volumne 329: 295-3005.

Mason, R.R. 1996. Dynamic behavior of Douglas-fir tussock moth populations in the Pacific Northwest. Forest Sci. 42(2):182-191.

Wickman, B.E. 1978. Tree mortality and top-kill related to defoliation by the Douglas-fir tussock moth in the Blue Mountains outbreak. Res. Paper PNW-233. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest & Range Experiment Station. 47 p.

Wickman, B.E., R.R. Mason, and G.C. Trostle. 1981. Douglas-fir tussock moth. Forest Insect & Disease Leaflet 86. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 10 p.

Pine-feeding Needleminers (*Coletechnites* spp.)

Hosts: Ponderosa, Jeffrey, lodgepole, piñon pine, and Monterey

Distribution in California: Generally throughout the range of individual host tree species. For lodgepole needleminer, Sierra Nevada lodgepole pine forests above 7,900 feet.

Identification: Adults of pine-feeding needleminers are small, narrow-winged, mottled, silvery-gray moths with a wingspan of about 10 mm. Eggs are too small, 0.2 mm in diameter, to be noticeable. Larvae are brown, 8 mm long when fully developed, and found mining within current year's needles or older needles. The pupae are elongate, cylindrical black, and about 6 mm long. Needles inhabited by third and fourth instar larvae turn a faded yellow-brown in color and have several tiny holes in them for frass disposal and larval exit.

Life History: The ponderosa pine and Jeffrey needleminer have one generation per year. Adult moths emerge, fly, and lay eggs in mid-late summer. Eggs are often laid inside old, previously mined needles. Eggs begin hatching in July. The tiny larvae move to green needles, bore in near the needle tip, and begin mining. Development continues slowly through the winter, and then accelerates rapidly with the coming of warm spring weather. Each larva completes its development in a single needle and pupates in the mined-out needle in midsummer. Mined needles drop prematurely.

The lodgepole pine needleminer has a two year life cycle. The adult females lay eggs in mid summer in previously mined needles or the base of the needle pairs. Larvae hatch and feed on the curved side of the needle and mine toward the tip. The larvae overwinter in the needle and

Defoliation caused by lodgepole needleminer

Photo: Beverly Bulaon

continue mining in the spring. In the spring, larvae move to new needles and continue mining. The larvae again overwinter in the needle and adults emerge the following summer.

Effects: Persistent infestations can cause severe discoloration, defoliation, and reduced growth of stems, shoots, and needles. Several years of heavy feeding may result in visible tree decline, as shown by reduced needle length and numbers. Severely weakened trees may become susceptible to further attack by bark beetles. Lodgepole needleminer infestation has been ongoing in Yosemite National Park along Tioga Road corridor since 1945, An earlier outbreak in association with mountain pine beetle in 1920 killed thousands of trees in the Park.

Similar Insects and Diseases: Similar symptoms, i.e., discoloration and defoliation, can result from scale insects, aphids, and needle cast diseases. However, only the needleminers leave characteristic holes on the mined needles. Infested needles will have transparent sections where miners were feeding. Needleminer activity is sometimes confused with beetle damage, particularly mountain pine beetle or twig borers. However, mountain pine beetles cause all the needles to fade, not just some; and twig borers kill the entire branch tip. Also, only the outer tips of needle miner-infested needles fade; the inner sections remain green.

Management Strategies: Although needleminers have the usual complement of natural controls, including parasitic insects (a biotic factor) and adverse weather (an abiotic or physical factor), these may not be effective in keeping numbers of needle miners below damaging levels.

High-value trees can be protected against needleminers using either of two chemical control approaches. The more conventional is individual tree spraying with commercial hydraulic spray equipment. The other uses insecticide implants inserted into holes drilled into the tree trunk. Both techniques depend on the same insecticide, acephate. Both are aimed at preventing establishment of the young larvae in green, uninfested needles. Timing is highly critical in the case of the foliar spray. In either case, some time is necessary before the trees' appearance will improve, as the old mined needles drop off.

References

Stevens, R. E., D.A. Leatherman and J.W. Brewer. 1996. Ponderosa Pine Needle Miners. Trees & Shrubs no. 5.544. Colorado State University Cooperative Extension. http://www.ext.colostate.edu/PUBS/INSECT/05544.PDF last accessed 4/23/08.

Stevens, R. E. 1973. A Ponderosa Pine Needle Miner in the Colorado Front Range. USDA Forest Service Research Note RM-228, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Stevens, R. E., and D. A. Leatherman. 1982. Implants and Sprays for Control of Ponderosa Pine Needle Miner in Individual Trees. USDA Forest Service Research Note RM-420, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Furniss R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA Forest Service, Miscellaneous Publication No. 1339. 654 p.

Stevens, R. E., J. W. Brewer, and D. T. Jennings. 1978. Life history and habits of Coleotechnites edulicola (Gelechiidas) a piñon needle miner in the Southwest. Journal of the Lepidopterists Society. 32(2): 123-129.

Struble, G.R. 1958. Lodgepole Needle Miner. USDA Forest Service, Forest Pest Leaflet 22. 7pg.

Budworms (*Choristoneura spp.*)

Hosts: Douglas-fir, true firs, and spruce

The probability of defoliation appears to be highest in stands where the basal area is comprised of greater then 30% host tree species, sites with vegetation types at the dry end of the white fir and Douglas-fir habitat series, stands with multi-storied structures as well as stands within boundaries of past budworm outbreaks.

Distribution in California: Four species of budworm are found in California, each in various forested regions. In the Sierra Nevada and North Coast Ranges, *C. californica* feeds on Douglas-fir. In the mountains of southern California, *C. carnana* feeds on bigcone Douglas-fir and on Douglas-fir on the west slopes of the Sierra Nevada. Modoc budworm, *C. retiniana*, feeds on true firs from northeastern California south through the Sierra Nevada to the mountains of southern California. The western spruce budworm, *C. occidentalis*, occurs in the northernmost counties of California and feeds on white fir and Douglas-fir.

Early instar western spruce budworm webbing and feeding

Photo: Ladd Livingston

Western spruce budworm injury

Photo: David McComb

Identification: Larval stages are the life forms most commonly detected. Early instar larvae are light green to light brown with dark heads. They start feeding in late spring as buds began to swell. Full-grown larvae are about 2.5 cm (1 in) long with brown heads and brown bodies and ivory colored spots. They are found from late June through mid July. Larvae feed on the current year's foliage and will be found in silken shelters of webbed, chewed needles, as will the shiny brown pupae from which the adults emerge in late July through mid August. Adults are mottled rusty-brown moths with wingspans of about 22 mm (7/8 in). Females lay eggs in masses of about 40 eggs each on the undersides of host tree needles.

Larvae are wasteful feeders and clip many more needles than they actually consume. The partially-eaten and severed needles turn reddish-brown as they dry and give host trees an overall reddish appearance which can be seen from quite a distance. This reddish appearance of the foliage is the signature for detection by aerial survey crews.

Life History: Spruce budworms have one generation per year. Both sexes fly. Adult moths emerge from pupal cases in late July or early August. The moths are extremely variable in color and pattern. Females mate and within 7 to 10 days deposit about 150 flat, scale-like eggs in several masses each containing an average of 40 eggs on the underside of needles. Larvae hatch in about 10 days, and seek sheltered places where they spin silken shelters called hibernacula in which they remain inactive through the winter. In early May, larvae leave the hibernacula to search for food. They initally mine current year needles, closed buds, or newly developing vegetative or reproductive buds. Larvae go through 6 instars and are fully-grown in 30 to 40 days after leaving their overwintering sites. Larvae pupate in webs of silk they have spun at feeding sites or elsewhere on the tree. The pupal stage lasts about 10 days.

Effects: Spruce budworm outbreaks play fundamental roles in forest development. Forest composition and structure may be significantly affected due to killing of numerous understory trees, and the reduction in growth rates and cone crops of overstory host trees. Over the long term, these effects may lead to spatially heterogeneous forest stands with mixes of host and nonhost trees and, possibly, lower overall forest densities. Infestations have cascading effects across trophic levels because budworm populations interact directly with predator populations such as birds and ants. Nutrient cycling is increased in infested stands by the rain of insect bodies and frass onto the soil surface and the changing nutrient and light conditions which benefit understory plants and surviving trees.

Prolonged outbreaks of high populations will cause radial and height growth reductions, topkill, and whole tree mortality. In a large outbreak, most of the stands will experience radial and height growth reduction along with some mortality. Severe defoliation and significant amounts of tree mortality will occur on about 15% of the total outbreak area during a large outbreak. In the most severe cases, over 80% of the trees may be killed.

In addition to foliage, budworm larvae feed heavily on staminate flowers and developing cones of host trees. This causes a significant decline in seed production.

Similar Insects: Spruce coneworm also feeds on Douglas-fir and white fir foliage, produces webbing like the spruce budworm, and can often be found cohabitating with spruce budworm larvae. However, spruce coneworm larvae can be distinguished by their longitudinally striped pattern. Douglas-fir Tussock Moth injury also look very similar to budworm, but DFTM feeding is concentrated in the upper canopy rather than uniformly throughout the crown; webbing is much less on DFTM infested trees.

Management Strategies: Thinning for the dual purpose of lowering stocking density and reducing percentage of host species to less than 30 percent of the overall stocking may help to reduce the effects of defoliation. Annual aerial detection surveys are conducted by state and federal cooperators across Washington and Oregon to detect occurrences of visible defoliation. Detection of defoliation from the air may trigger further evaluations on the ground.

Suppression treatments using chemical insecticides and the microbial insecticide B.t. may be desirable and feasible in well-defined high-value areas where heavy damage is expected. High volume hydraulic insecticide treatments have been applied to protect Douglas-fir seed crops and implanted systemic insecticides have been used to protect individual high value trees.

References

Furniss R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA Forest Service, Miscellaneous Publication No. 1339. 654 p.

Pandora Moth (*Coloradia pandora*)

Hosts: Ponderosa, lodgepole pines, Jeffrey pine in California; sometimes coulter and sugar pines are also attacked.

Adult pandora moth

Photo: Terry Spivey

Pandora moth larva

Photo: US Forest Service

Pandora moth defoliation, Inyo National Forest, California

Photo: Don Owen

Distribution in California: Currently Eastern Sierra Nevada, and northeastern California. Outbreaks were once noted in southern California in the 1950's and 1960's, but none has been recorded on the west side or south since then.

Identification: Larvae consume older needles of host trees in the spring and early summer. By mid-June, an affected tree may be completely bare. Feeding generally ceases just before the new year's foliage emerges.

Adult pandora moths are very large and heavy bodied, about 2.5 to 4.0 cm (1 to 1½ inches) long, with a wingspread of 7 to 11 cm (3 to 4 in). The forewings are grayish-brown and their hind wings are pinkish in color, each are marked with a black dot and a dark wavy line. The males are distinguished by having large, feathery antennae. Eggs are globular, pale green to bluish gray, and often laid in groups of about 15 on foliage, branches, tree boles, or various other structures. Newly hatched larvae are black, hairy and have shiny black heads. As they grow larger, they become lighter in color and are eventually gray with light yellow bands along the lengths of their bodies. The later larval stages reach about 7 cm (2¾ in) in length and have short spines on each abdominal segment. The pupal stage is about 3 to 4 cm (1¼ to 1½ in) long, dark purplish in color with a tough shell and is found just below the soil or duff line on the forest floor.

Life History: The pandora moth has a 2-year life cycle. Adults appear in June and early July. They are strongly attracted to street lights and when populations are high, can cover the sides of buildings or other structures near lights. Females lay eggs on all parts of the host tree, generally in groups of 6 to 15. The eggs hatch in the fall and young larvae overwinter in groups near the buds of the host tree. They begin feeding aggressively in the spring and are mature by mid-June. The fully-grown larvae climb down from the host tree and pupate in the ground, just below the surface. The pupae spend an entire year in the soil and new adults emerge in the summer to begin the next generation. Typically, an "outbreak cycle" will consist of three or four successively larger generations followed by a sudden collapse back to an endemic level.

Effects: Defoliation by the pandora moth reduces growth and vigor of host trees. By itself, the pandora moth is not a significant tree killer, but may weaken trees and make them more vulnerable to other agents such as bark beetles.

During outbreaks, defoliation can be severe over large areas. Due to the 2-year life cycle, however, defoliation occurs only during alternate years. However, some growth loss and even mortality can occur especially if trees are severely stressed from additional factors such as drought or heavy dwarf mistletoe infections.

Similar Insects: May be confused with sawfly defoliation. However, sawfly larvae have smooth bodies, are much smaller (18 to 25 mm long), and have eight pairs of leg-like appendages on the abdomen. Defoliation caused by sawflies usually occurs on an individual or small group of trees and is not widespread like that of a pandora moth outbreak.

Management Strategies: Given the infrequent occurrence and limited long-term damage caused by this insect, the pandora moth has not received management attention in the forest setting. Outbreaks generally run their courses after three or four generations and are brought to a halt by a naturally occurring virus that affects the larval stage, spreading rapidly through the population. Some insecticides have been tested for use in urban environments but have shown limited efficacy.

References

Fitzgerald, S.A. 1992. Controlling pandora moth in central Oregon forests and landscapes. Oregon State University Extension Service EC 1383. 4 p.

Patterson, J.E. 1929. The pandora moth, a periodic pest of western pine forests. USDA Technical Bulletin 137. 19 p.

Schmid, J.M., and Bennett, D.D. 1988. The North Kaibab pandora moth outbreak, 1978-1984. USDA Forest Service, Rocky Mountain Forest and Range Exper. Sta. Gen. Tech. Rep. RM-153. 19 p.

Susan K. Hagle, S. K., K. E. Gibson, S. Tunnock. 2003. A Field Guide to Diseases & Insect Pests of Northern & Central Rocky Mountain Conifers. United States Department of Agriculture, Forest Service, Northern and Intermountain Regions Report number: R1-03-08.

Carolin, V.M and J.A. Knopf 1968. The Pandora Moth. USDA Forest Service, Forest Pest Leaflet 114.

Fruittree Leafroller (*Archips argyrospila*)

Hosts: Almost all oak species. It also attacks numerous fruit and nut trees: almond, apple, apricot, caneberries, cherry, citrus, pear, plum, prune, quince, and walnut. In addition, a large number of ornamental and native trees are affected: ash, birch, California buckeye, box elder, elm, locust, maple, poplar, rose, and willow.

Distribution in California: Throughout California.

Fruittree leafroller larva

Photo: Laura Merrill

Fruittree leafroller

Photo: US Forest Service

Fruittree leafroller adult

Photo: James Hanson

Identification: The adult moth has a bell-shaped outline when viewed from above with a wing span of 1.5 to 2.2 cm (5/8 to 7/8 inch). The forewings are mottled shades of brown and tan with gold-colored flecks, while the hind wings are whitish to gray.

The eggs are laid in irregular flat masses primarily on twigs and smaller branches. The egg mass is coated with a dark gray or brown cement that bleaches and later turns white; this covering becomes perforated (pinholes) in spring as the larvae hatch and emerge.

A newly hatched larva is entirely green except for a black head and small hard plate just behind the head. As the larva matures, its head lightens to dark brown and the plate becomes a tan to olive-green color. At maturity the larvae are 1.9 to 2.5 cm (3/4 to 1 inch) long. They often drop to the ground on a silken thread when disturbed. The pupa is just under 1/2 inch long, light to dark brown, and usually formed within a rolled leaf.

Life History: Fruittree leafroller overwinters as an egg. Eggs hatch into tiny larvae in spring from March to as late as mid-May in cooler areas. Larvae feed on leaves for about 30 days, then pupate in a loose cocoon formed in a rolled leaf or similar shelter. Eight to 11 days later the adult emerges from the pupa. The moths live only about a week, during which time they mate and lay eggs. They fly from May to June in various localities, and in any one area the flight usually lasts about 3 weeks. Only one generation occurs each year.

Effects: The larvae feed on tender new leaves, giving them a ragged appearance. Leaves are rolled and tied together with silken threads to form compact hiding places. In severe cases trees may be partially or completely defoliated with silken thread covering the entire tree and ground below. Even if completely defoliated, trees that are otherwise healthy can be expected to recover.

Fruit on trees are also attacked by the larvae, and young fruit may fall because of deep feeding grooves made just after fruit has formed. Less severely damaged fruit remain on the tree and develop characteristically deep, bronze-colored scars with roughened netlike surfaces that are mostly cosmetic, although the fruit may be deformed.

Similar Insects: Some people mistake fruittree leafroller for California oakworm because of its prevalence on oaks. However, fruittree leafroller is green with a black head, and California oakworm has yellow, black, and gray stripes on its side and a large brown head.

Management Strategies: A number of insects utilize the fruittree leafroller as food: certain tachinid flies and ichneumonid wasps appear to be its main parasites, while lacewing and certain beetles are its most common predators. Birds sometimes feed on the larvae and pupae but seem to prefer other insects. These natural enemies often help to keep the fruittree leafroller at low levels, but outbreaks of leafrollers occasionally occur.

Bacillus thuringiensis (*B.t.*) is effective against the larval stages of the fruittree leafroller. B.t., is a bacterial preparation that causes a disease in many kinds of caterpillars but does not harm other beneficial insects, birds, man, or other organisms. Thorough spray coverage of the tree is required for control. (*B.t.* will also control other caterpillars present at the time of application.) *B.t.* is only effective on fruittree leafroller larvae when they are small (less than 1/2 inch long) and usually requires more than one application.

References

Coates, W. W., R. A. Van Steenwyk, W. J. Bentley, K. R. Day, K. A. Kelley, J. L. Caprile. 2007. UC Pest Management Guidelines: Apricot Fruittree Leafroller. UC ANR Publication 3433. http://www.ipm.ucdavis.edu/PMG/r5300211.html. Last accessed April 23, 2008.

Moore, W. S., C. S. Koehler, and L. S. Frey. 1982. Fruittree Leafroller on Ornamentals and Fruit Trees. Oakland: Univ. Calif. Div. Agric. Nat. Res. Leaflet 21053c.

Dreistadt, S. H., J. K. Clark, and M. L. Flint. 1994. Pests of Landscape Trees and Shrubs: An Integrated Pest Management Guide. Oakland: Univ. Calif. Div. Agric. Nat. Res. Publ. 3359.

Sweicki, T. and E.A. Bernhardt. 2006. A field guide to insects and pathogens of California oaks. USDA Forest Service, General Technical Report PSW-GTR-197. 151 pgs.

Fall Webworm (*Hyphantria cunea*)

Hosts: Willow, alder, ash, chokeberry, cottonwood, and madrone

Distribution in California: Throughout the range of suitable hosts.

Fall webworm larva

Photo: Danny Cluck

Fall webworm webs on Madrone

Photo: Danny Cluck

Identification: Larvae feed on foliage, forming large webs in the branches of trees. Webs are noticeable in the fall when larval feeding takes place. There are two types: a blackheaded or northern fall webworm and a redheaded or southern fall webworm. Larvae of the southern are yellowish-tan with red or orange colored heads and brownish hair that arises from reddish-brown tubercles. Larvae of the northern fall webworm have a black head with a pale yellowish or greenish body that has a dark stripe on the back, and long white hairs rising from red or black tubercles. The black-headed type predominates in the West. Adults are white in color with orange markings on the body and legs. The wings have some black spots and a wing expanse of approximately 3.0 cm (1¼ inches).

Life History: Fall webworm has one generation per year. Adults appear and lay eggs in late June and early July. The eggs hatch and the small larvae feed on both leaf surfaces while larger larvae will consume the whole leaf. Larval feeding continues until mid-September. The insect overwinters in the pupal stage in a transparent cocoon in the soil, leaf litter, or on tree trunks.

Effects: This insect causes minor defoliation in most forested situations. It can cause loss of visual quality in ornamental plantings. Areas can be chronically infested, but mortality is rare.

Similar Insects: The western tent caterpillar is sometimes confused with the fall webworm, due to both having dark heads and dark stripes down their backs. However, western tent caterpillars feed in the spring while fall webworm feeds in the fall.

Management Strategies: Management options include physical removal of the nests, conservation of natural enemies, applications of *B.t.*, and the use of other foliar and systemic insecticides.

References

Johnson, W.T. and H.H. Lyon. 1991. Insects that Feed on Trees and Shrubs. Cornell University Press. Ithaca and London. 560 pp.

Sawflies (*Neodiprion* spp., *Zadiprion* spp.)

Hosts: Ponderosa and pinyon pines, and white fir

Neodiprion abietis feeding on white fir

Photo: Don Owen

Identifiaction: Many species are covered here so there is some variation in appearance. However, an adult female has a length of 8 to 10 mm (1/3 inch), with a stout and thick-waisted body. The background color varies from light to dark brown, with yellow-red-white markings common. The two pairs of wings are clear to light brown with prominent veins. The adult male is slightly shorter with feathery antennae and a more slender, thick-waisted body. It generally has brown to black wings, similar to females. Pine sawfly larval appearance varies by species and by larval instar, but most are green or yellowish green in body color with black, tan or orange head capsules.

Life History: Larvae are found in either spring-summer or fall-winter feeding gregariously on older foliage, consuming only the outer needle tissue while leaving the central ribs intact. The central ribs later turn yellow brown and break off. Later instar larvae feed singly and consume most of the needle. Eggs are laid in slits cut in the edge of living pine needles. A papery cocoon covers pupae. Adults are broad waist wasps. Infested trees have sparse foliage and thin crowns.

Effects: Although the defoliation can appear rather spectacular, it rarely leads to tree mortality. These defoliators feed fairly early in the season. They generally consume older foliage, and pupate before the new foliage emerges. Affected trees are not often bare of foliage for very long. However, the same trees are frequently defoliated year after year if infestation continues. In general, defoliation reduces growth, and repeated defoliation may result in top-kill and

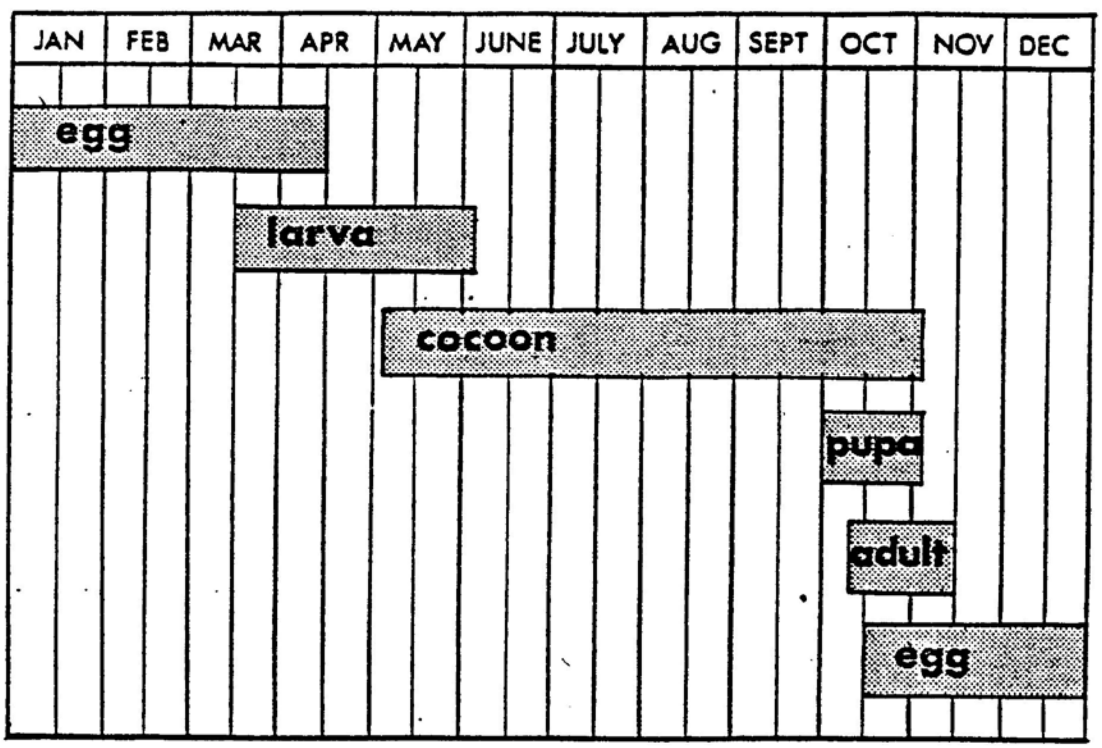


Figure 19. Life cycle for pine sawflies

eventual tree mortality.

Pine sawflies typically attack open-grown trees or areas where pine is growing at a low density; plantations are especially vulnerable to infestation. During the year 2000, some of the plantation ponderosa pines on the Klamath and Shasta-Trinity National Forests were defoliated by the pine needle sheath miner, *Zelleria haimbachi* and from pine sawflies, *Neodiprion fulviceps*.

Similar Insects: See pandora moth and pine butterfly.

Management Strategies: Although most conifers are adaptable to a wide range of site conditions, it is always advisable to match the tree species to sites favoring that species. Management suggestions also include herbicides to reduce hardwood competition and monitoring plantations frequently for sawfly damage.

References:

Fairweather, M. L., J. McMillin, T. Rogers, D. Conklin, B. Fitzgibbon. 2006. Field Guide to Insects and Diseases of Arizona and New Mexico. United States Department of Agriculture, Forest Service, Southwestern Region. MB-R3-16-3. http://www.fs.fed.us/r3/resources/health/field-guide/index.shtml. Last accessed April 23, 2008.

Dunbar, C. S. and M. R. Wagner. 1990. Distribution of ponderosa pine (Pinus ponderosa) feeding sawflies (Hymenoptera: Diprionidae) in the United States and Canada. Entomol. News 101: 266-272.

Furniss R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA Forest Service, Miscellaneous Publication No. 1339. 654 p.

McGregor, M. D., and L. O. Sandin. 1969. Pinyon sawfly, Neodiprion edulicolis Ross. USDA Forest Service, Forest Insect and Disease Leaflet 117. 10 p.

McMillin, J. D., G. Hengxiao, M. R. Wagner & X. Long. 1996. Host density and elevation effects on the spatial distribution patterns of pine sawflies in eastern Arizona and southwestern China. Forest Ecology and Management 86: 151–161.

McMillin, J. D. and M. R. Wagner. 1993. Influence of stand characteristics and site quality on sawfly population dynamics. p. 333–361. In: (M. R. Wagner & K. F. Raffa, eds.) Sawfly Life History Adaptations to Woody Plants. Academic Press, Orlando, FL.

McMillin, J. D. and M. R. Wagner. 1997. Chronic defoliation impacts pine sawfly (Hymenoptera: Diprionidae) performance and host plant quality. Oikos 79: 357–362.

McMillin, J. D. and M. R. Wagner. 1998. Influence of host plant versus natural enemies on the spatial distribution of a pine sawfly, Neodiprion autumnalis (Hymenoptera: Diprionidae). Ecological Entomology 23: 397–408.

Schultz, D. 2001. Evaluation of Goosenest Plantations (FHP Rept. No. N01-05). United States Department of Agriculture, Forest Service, Northern California Shared Service Area

Silverspotted Tiger Moth (*Lophocampa argentata)*

Hosts: Douglas-fir, true firs, spruce and pines

Distribution in California: Coast and central ranges of northern California

Identification: Larvae feed on foliage and make large, irregular silken tents in the upper branches. The branches near the web are often completely defoliated. Mature caterpillars are about 4 cm (1/2 inch) long, reddish brown to black in color and have tufts of black and yellow hairs on their back. Adult moths have a wing span of 3.5 – 5 cm (1 ½ - 2 inches). The dark reddish brown forewings and thorax have numerous silver spots and the hindwings are yellowish white.

Life History: The tiger moth has one generation per year. Adult moths lay masses of green eggs on foliage and twigs of host trees. Eggs hatch in about three weeks. Young caterpillars begin feeding gregariously on needles and producing webbing. As larvae grow, they enlarge the web. Larvae overwinter in the webs in groups. In April and May, larvae resume feeding and expanding their webs. At this point the insects and the webs become very noticeable. As they approach maturity, they crawl out of the web and feed singly. In June, the mature larvae spin oval cocoons on the tree or in litter on the ground, where pupation occurs.

Populations of this insect usually remain at low levels, presumably due to predators, parasites, diseases, and cold winters.

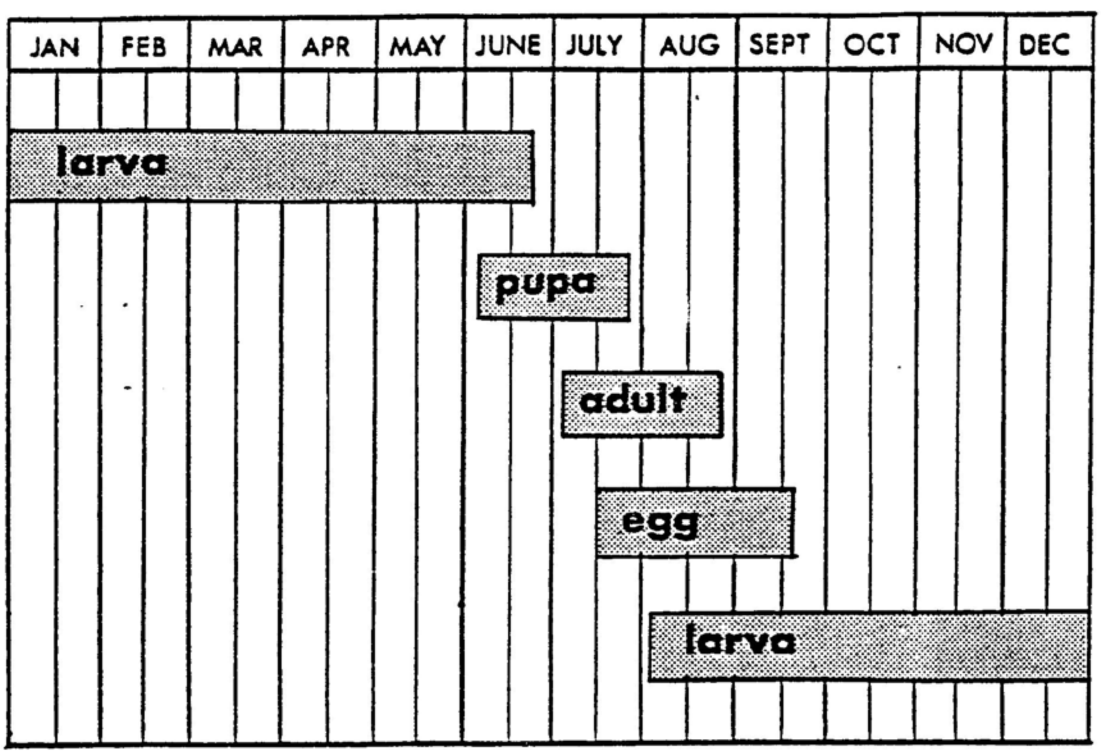


Figure 20. Life cycle of Silverspotted Tiger Moth

Effects: Larvae feed gregariously in webs primarily on young trees. Although the webs and larvae can be very noticeable in spring, this insect causes only minor defoliation. Permanent tree injury rarely results from feeding that is usually limited to the upper foliage.

Similar Insects: Tents are similar to those formed by tent caterpillars such as the western tent caterpillar.

Management Strategies: Larval parasites, particularly Tachinid flies, can dramatically reduce moth populations such that control is usually not required. High levels of parasitism cause most large infestations or outbreaks to collapse in one or two years. On high value trees, prune off and destroy infested branches and caterpillars as soon as infestation is apparent. Spraying of tiger moth infestations is rarely warranted. Insecticides are most effective against small larvae and should be applied as soon as the infestation is noticed to minimize foliage damage.

References:

Flowers, R. and A. Kanaskie, 2007. Silver-Spotted Tiger Moth. Oregon Department of Forestry. www.oregon.gov/ODF/PRIVATE_FORESTS/fh.shtml. Last accessed April 23, 2008.

Tent Caterpillars (*Malacosoma* spp)

Hosts: Western Tent Caterpillar (*M. californicum*): Aspen, willows, cottonwoods, and mountain mahogany. Pacific Tent Caterpillar (*M. constictum*): Oaks primarily. Forest Tent Caterpillar (*M. disstria*): Oak, poplar, birch, alder, willows, hawthorne, and rose.

Distribution in California: Throughout the range of suitable hosts

Identification: Tent caterpillars are an early season defoliator with feeding damages typically occurring between May and June. Symptoms include moderate to complete defoliation of trees; large silken tents on branches; and presence of larvae in and around the tents. Trees repeatedly defoliated will have sparse foliage, minor branch dieback, and in some cases, tree mortality.

Western tent caterpillar larvae

Photo: Whitney Cranshaw

Each species also have subspecies that are identified by their geographic location rather than morphology, all of which are still very similar with slight variations. Most mature larvae are 4 to 5 cm (1½ to 2 inches) long and vary widely in coloration. Their heads are blue to black and body color patterns are mixtures of black, orange, and blue. Larvae are usually quite hairy.

Life History: Tent caterpillars have one generation per year. Young larvae feed gregariously, but as they mature in late May or early June, they disperse over the tree and feed singly. Larvae overwinter as first instars inside egg masses glued around twigs. Larvae emerge from egg masses in spring and construct silken tents on branches that are used for shelter and molting during the daytime. As larvae mature, they disperse and become solitary feeders. Moths emerge from cocoons and glue egg masses to live twigs that are less than 2 cm in diameter.

Effects: Heavy defoliation of aspen for a number of years will cause growth loss and branch dieback. Some mortality may also occur during prolonged outbreaks. Outbreaks, however, are generally short lived, generally lasting 2 to 3 years.

Similar Insects: See fall webworm.

Management Strategies: If nothing is done, tent caterpillar populations collapse in 2-3 years from the combined effects of parasites and disease. In most forest situations control with insecticide is not warranted. In high value trees, prune off and destroy caterpillars and tents as soon as the infestation is apparent. Early morning and evenings are the best times to prune out tents since the caterpillars tend to congregate in their nests at night. Insecticides can be used most effectively against small larvae in the early spring and should be applied to tents and surrounding foliage in the early morning or evening.

References

Flowers, R. and A. Kanaskie. 2007. Western Tent Caterpillar. Forest Health Note. www.oregon.gov/ODF/PRIVATE_FORESTS/fh.shtml. Last accessed April 23, 2008.

Sweicki, T. and E.A. Bernhardt. 2006. A field guide to insects and pathogens of California oaks. USDA Forest Service, General Technical Report PSW-GTR-197. 151 pgs.

Alder Flea Beetle (*Altica ambiens*)

Hosts: Alder, willow, and poplar

Distribution in California: Throughout the range of suitable hosts

Identification: Larvae are skeletonizers, meaning that they feed on the tissue between the veins, but leave the veins intact. Adults chew holes in the leaves. Adult beetles are dark shiny blue, and about 5 mm (1/8 inch) long. The mature larvae are a little longer and narrower than the adults, brown to black above and yellowish below.

When populations of this beetle are high, feeding damage turns patches of alder brown leading land owners/ managers to believe that the alder is dead

Life History: One generation is reported per year. Adults hibernate during the winter in duff at the base of trees and in other sheltered places. They emerge in early spring to resume feeding. Eggs are laid in clusters on foliage. Larvae hatch and begin feeding within a few days.

Effects: No long-term effects are documented. Outbreaks are generally short lived and sporadic with heavy defoliation. Trees tend to recover quickly.

Similar Insects: Although other defoliators feed on alder, outbreaks of these other insects have not been reported.

Management Strategies: Damage by this insect rarely reaches levels where insecticide use is warranted. For high value trees, tactics geared toward maintaining plant vigor, such as watering and fertilizing as needed, are recommended.

References

Berryman, A.A. 1989. Forest Insects Principles and Practice of Population Management. Plenum Press, New York, New York. Pg. 157.

Coulson, R.N. and J.A. Witter. 1984. Forest Entomology Ecology and Management. John Wiley & Sons, Inc. New York, New York. Pg. 381.

Furniss, R.L. and V.M. Carolin. 1977. Western Forest Insects. US Department of Agriculture Forest Service. Miscellaneous Publication No. 1339. Pg 315.

Leaf Beetles (*Chrysomela* spp., *Altica* spp., *Pyrrhalta* spp., and others)

Hosts: Willow, cottonwood, poplar, alder

Little is known about the conditions under which leaf beetle populations can thrive. Large buildups in populations seem to occur at irregular intervals, and host plants growing under a variety of conditions can be affected.

Distribution in California: Throughout the range of suitable hosts

Identification: In the adult stage, many of the leaf beetles resemble “lady bugs”, both in body shape and coloration. Others are more elongated and may be striped along the wing covers. Some, such as the alder flea beetle, have a metallic color. Larvae are darkly colored, elongate, strongly segmented, and have three pairs of legs. Feeding on the host plant takes two forms; adults make notches in the margins of leaves during their maturation feeding, and larvae “skeletonize” the leaves as they develop, leaving the veins intact while consuming the rest of the leaf tissue.

Life History: Most leaf beetles have one-year life cycles, although several species of *Chrysomela* have two to several generations per year, depending on temperature. Typically, the adult beetles overwinter in the duff layer or in bark crevices on their hosts. They emerge from their overwintering sites in the spring shortly after budburst. The adults feed on the newly emerged foliage, notching the leaf margins. Shortly thereafter they mate and lay masses of eggs on the undersides of leaves. Larvae emerge within a few days and feed in groups near the old egg masses. After several molts, each mature larva forms a pupal case on a leaf. The new adults emerge in the fall and look for overwintering sites. In those cases where several generations occur in one year, larvae can be seen virtually throughout the spring and summer skeletonizing the leaves of host plants.

Effects: Leaf beetles generally do not kill their host plants. Feeding by leaf beetles reduces the photosynthesizing capability of the host, causing stress that may render it more susceptible to other damaging agents. Typically, some plants will expend energy producing additional foliage after being defoliated by leaf beetles. Heavy defoliation along stream channels can lead to loss of shade and a temporary increase in water temperature.

Management Strategies: Leaf beetles have only been controlled in urban settings where their feeding activity causes concern for the health of landscape trees and for loss of shade. In forest and riparian situations, the effects of leaf beetles seem to be transitory, and as such have not required management intervention.

References

Furniss, R.L., and Carolin, V.M. 1977. Western forest insects. USDA Forest Service Miscellaneous Publication 1339. 654 p.

Sucking Insects

All of the insects discussed in the preceding section feed upon the tissues of trees by ingesting the solid parts. All of them have mandibulate or chewing mouthparts. There is another large and important group of insects that live upon the sap of plants. Their mouthparts are of the sucking type in which the parts have become slender, bristle-like organs enclosed in a sheath. The mouth parts thus form a beak, used to pierce the tissues and suck the fluids. The effect of sucking insects upon trees is much less conspicuous than is the effect of defoliators and bark beetles. Only a few species seem able to kill trees directly.

Sucking insects may injure forest trees in two ways: (1) directly by sucking the sap, thus robbing the plant of a part of its supply of food and water; and (2) indirectly by producing necrotic spots or swellings. The sucking insects attacking trees belong to two orders: the Hemiptera and Homoptera.

Hemiptera (True Bugs): Members of this order are the true bugs and it is only to this group that the name bug can be correctly applied. There is only one known true bug of any consequence to forest trees in the northwest and that is the western conifer-seed bug, *Leptoglossus occidentalis*. The nymphs and adults of this insect insert their long proboscis or beak into the cones of Douglas-fir and pine and suck the juices from the seeds.

Homoptera (Aphids, Adelgids, Scales, Spittlebugs): The various members in this order make up the majority of sucking insects injuring forest trees.

Aphids on black oak

Photo: Danny Cluck

Aphids: Among the homopterous sucking insects the family Aphididae stands out prominently as an injurious group. They are abundant in numbers, both in individuals and of species. They are also generally distributed that it is scarcely possible to find a tree of sapling size or larger that is not infested by them to a greater or lesser degree.

The aphids are usually very small, soft-bodied insects with pear-shaped bodies. The legs are long and slender. Aphids may be black or greenish, either winged or wingless. When wings are present, all four of them are transparent, delicate, and with few simple or branched veins.

Various aphids have different habits. Some of them live on the bark of the trunk, branches, and twigs. Others confine their feeding to the needles or roots. Some aphids provide shelter for themselves by forming galls, or by secreting a flocculent, wax-like material that collects over the insects and affords them some protection from their enemies, weather, and certain insecticides. Still others live unprotected on the surface of the trees.

All aphids excrete a sweet material called honeydew, which is highly prized for food by ants and other insects. For this reason, it is a common sight to see ants busily collecting this sweet liquid. In some instances the ants care for the aphids and in return receive honeydew. It is because of this relationship that aphids are sometimes called ant cows. A sooty mold fungus may develop on the honeydew excreted by the aphids and some scale insects. The black material consists of the fungus hyphae. The hyphae do not penetrate the living needle tissue. Although sooty needles are unsightly and some interference with their physiological functions must result, there is no apparent injury to affected trees. Preventing honeydew formation by controlling the aphids is the best way of dealing with the sooty mold problem. At certain times, the honeydew itself can be a nuisance when it drips onto picnic tables, etc. It can be washed off with water.

When aphids occur in comparatively small numbers, the direct injury caused is comparatively slight. However, when they become very abundant, as they frequently do under favorable weather conditions, their injury to the trees is often great. Only a few species may kill trees. Most of the injury that they cause results in a reduced rate of growth and in a generally unthrifty condition. Trees injured by aphids may succumb to secondary insects or fungus diseases.

Early season control is the key to successful treatment. Usually by the time damage is noted it is too late for effective treatment. Only in nurseries, young plantations, and on ornamental trees do aphids and scales generally warrant control. During the growing season contact or systemic insecticides may give satisfactory control. The over wintering stages may be destroyed by a dormant spray.

Scales: The scale insects are in the superfamily Coccoidea. Two species, the pine needle scale, *Phenacaspis pinifolae*, and the black pine-leaf scale, *Nuculaspis californica*, attack the needles of pines and occasionally other conifers, and are the most common scales on forest trees. Infestations are often associated with conditions where dust and smoke are found in the atmosphere. Economics dictate that damage is usually greater in Christmas tree plantations and ornamentals than in natural forest situations. Control can be achieved by the timely use of conventional insecticides.

Spittlebugs: These insects in the family Ceropidae are called spittlebugs because of the mass of white froth, resembling spittle, which covers odd-looking hopper-like insects. The insects are well protected by this frothy secretion. The adults are known as froghoppers.

Spittlebugs are more common on pines, but do occur on other species. Heavy infestations can seriously affect young trees. Chemical controls for individual trees are available.

Mites: The mites, in the class Arachnida, do not belong to the same class as the insects, class Insecta. However, most people consider them as kinds of insects and the entomologist is usually called upon to provide information on them. They have bodies divided into two segments instead of three and have four pairs of legs instead of three. The mites are extremely small and have pointed, piercing mouth parts.

Most of the mites considered to be important on forest or ornamental trees are called spider mites in the genera *Tetranychus* and *Paratetranychus*. They suck the juices from needles causing spotting, fading, yellowing, or heavy needle fall. Heavy infestations make the trees appear as if they were scorched. Accumulations of silvery webs are often associated with the damage.

Populations of mites often increase after periods of long, dry, hot weather and in areas receiving repeated insecticide treatments. "Washing" individual trees with high water pressure, applying dormant sprays, and some insecticides, or miticides, can achieve direct control.

Black Pineleaf Scale (*Dynaspidiotus californica*)

Hosts: Numerous pine species, but most damaging to ponderosa, Jeffrey, sugar, and Monterey pines; also occurs on Douglas-fir.

Distribution in California: Throughout the forested regions of California

Black pineleaf scale

Photo: Don Owen

Identification: Foliage is sparse and needles are shorter than normal. Foliage is blotched with yellowish necrotic areas. Gray to black, oval-shaped scales about 2 mm (1/10 inch) long appear on the needles.

Life History: Scales overwinter on the foliage. In early summer, winged males emerge and mate with immobile females. Each female produces a mass of yellowish eggs that remain under the protective scale covering. The eggs hatch within a few days, releasing the nymphs, or crawlers.

The crawlers move freely along the needles, and many are transported to new hosts by air currents. Most population dispersal takes place during this stage. When the crawlers settle, usually along the flat inner surfaces of young needles, they insert their mouthparts into the needle and become immotile..

After the first molt, they secrete a waxy covering that enlarges with subsequent molts to accommodate their growth. The scale covering, or shell, is grayish black and has a lighter colored central prominence. Its shell distinguishes this insect from a common associate, the pine needle scale (*Chionaspis pinifoliae* (Fitch)), which has a uniformly whitish and narrower shell.

Protected under their shells, females lose their appendages and mobility. They are about 0.1 inch (1 to 1.5 mm) in diameter and more abundant than the males. Males are about one and a half times longer and slightly narrower than the females. Unlike the females, adult males have fully developed legs, antennae, and wings; they can crawl about or fly.

At the southern end of its range, the insect often has two generations per year. In southern California, the first generation of crawlers develops from May 15 to June 15; the second generation from August 1 to 15. And if fall and early winter are warm, some scales start a third generation before over-wintering.

Effect: Endemic populations of up to one scale per 2 inches (5 cm) of needle do not noticeably damage healthy trees. However, large populations reduce the number, length, and retention period of needles. Radial growth and terminal growth are also reduced. At this stage, the weakened tree may be attacked and killed by bark beetles.

Where scales have fed, the needles are often blotched with yellowish necrotic areas. These discolored areas are more pronounced in the spring, when they are not obscured by new foliage. By fall, affected needles drop off and leave the tree with sparse, short foliage. On heavily infested trees, scale bodies, often tightly packed against each other, can be seen along the needles

Similar Insects and Diseases: The pine needle scale causes the same type of damage but its scales are white rather than black. Infestations of aphids or spider mites and ozone injury also produce yellow blotches on foliage.

Management Strategies: Infestations are commonly associated with environmental conditions that disrupt the normally effective control exerted by the scale's natural enemies. Accumulations of dust from roads, excavations, or industrial plants, for example, have been known to cause outbreaks. Around orchards or mosquito habitat, repeated use of insecticides may also be associated with outbreaks if the spray harms the scale's natural enemies.

Natural enemies that normally keep black pineleaf scale populations at low densities include several species of parasitic wasps, of which a species of Encarsia is most important. Ladybird beetles also prey on this insect.

In addition, the rapid onset of freezing temperatures can reduce scale populations, particularly in areas where the microclimate is such that the scales do not become conditioned to cold.

Infestations can be reduced below damaging levels by properly timed insecticidal sprays or trunk implantations of systemic insecticide.

Scale populations apparently become adapted to individual trees and, therefore, may not rapidly colonize nearby host trees of the same or other species. This adaptation indicates that maintenance of forest stand diversity may decrease the potential of widespread outbreaks.

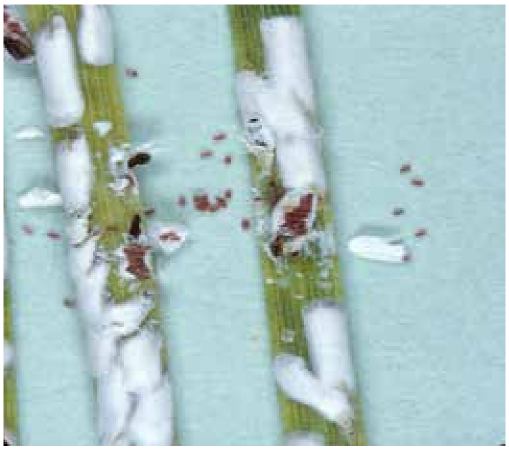
References

Furniss, R.L., and Carolin, V.M. 1977. Western forest insects. USDA Forest Service Miscellaneous Publication 1339. 654 p.

Pine Needle Scale (*Chionaspis pinifoliae*)

Hosts: All pines, Douglas-fir and spruce

Distribution in California: Throughout the forested regions of California. Damage is especially noticeable on ornamental pine and spruce trees growing along dusty roads.



Pine needle scales and eggs on ponderosa pine

Photo: Don Owen

Identification: Insects feed by sucking sap from needles. Needles turn blotchy yellow. White, elongated oval scales about 3 mm (1/10 inch) appear on the needles.

Life History: The pine needle scale has two generations per year. The mature female scales are most conspicuous. They are almost pure white, slender at the front with a wider rear end. Males are smaller and slender and rarely seen. Twenty to 30 eggs are laid in the fall and overwinter beneath the dead female scale. Eggs hatch in May and the nymphs, or "crawlers", move to new green needles to feed. Within a few weeks, the crawlers find new feeding sites, insert their mouthparts into needles, and molt into an immobile stage that secretes the characteristic white scale covering. The scales reach maturity by mid-summer. Winged males emerge from under the scales to mate with the immobile females. Eggs are produced immediately and the new generation mature by fall and lay the overwintering eggs.

Effects: Heavy infestations over several years can kill young trees and severely weaken larger trees, predisposing them to attack by other pests.

Similar Insects and Diseases: See black pineleaf scale. Damage may be similar to that caused by other agents that discolor needles such as pine needle casts, winter desiccation, drought, and aphids. If scales are present, diagnosis is assured.

Management Strategies: Dust control will prevent damaging infestations along roadsides. High valued ornamentals or Christmas trees may be sprayed with insecticides. Insecticides are most effective when sprayed during the crawler phase.

References

Furniss, R.L., and Carolin, V.M. 1977. Western forest insects. USDA Forest Service Miscellaneous Publication 1339. 654 p.

Plantation Insects

Plantation insects are receiving greater attention as more forestland is intensively managed and the acreage in plantations grows. Also, plantations and young trees are currently being affected to the same degrees as mature stands due to climatic changes, and these insects are expected to cause more problems.

Plantation insects cause impacts to young trees by (1) killing of lateral branches and terminal leaders; (2) deformation of trees, resulting in forked or multiple tops; (3) reduction of tree growth which prolongs the time required for trees to reach merchantable size; and (4) occasionally trees are killed directly. Seedlings and saplings, in particular, are negatively impacted by competing vegetation. When pest damage is added as a stressor to this situation, the result can be stagnation or mortality.

Injury to buds and shoots may be caused by caterpillars, weevils, bark beetles, midges, aphids, or scale insects. Some of these insects also feed on other plant parts such as foliage, cones, and branches. By far the most frequently observed damage to pine shoots is caused by tip moths and shoot borers belonging to the order Lepidoptera (moths and butterflies).

Most of these shoot insects are important in young, intensively managed stands or replanted forested areas. Forest managers can plan ahead to minimize impacts caused by shoot insects.

Western Pine Shoot Borer (*Eucosma sonomana*)

Hosts: Ponderosa, lodgepole, Jeffrey, knobcone and Bishop pines.

Distribution in California: Throughout the pine forests of California; damage is most common east of the Sierra Nevada and Cascade crests in northeastern California. It is common in young even-aged stands, especially single species plantations. Trees are most likely to be infested when they are between 3 and 24 ft tall.

Western pine shoot borer adult

Photo: US Forest Service

Shortened terminal indicative of western pine shoot borer

Photo: Don Owen

Identification: Infested host leaders have reduced growth, with the needles often bunched together to give a "bottle brush" appearance. Needle length within infested shoots is usually reduced by about one-third. Occasionally, an infested shoot is slightly swollen and may contain an exit hole where the larva has emerged. Infested lateral shoots and small leaders are sometimes killed. On lodgepole pine, the terminal is often killed. If an infested shoot is cut longitudinally, the pith will be dark where larval feeding has occurred. Larvae are cream-colored with a dark head capsule and three well-developed pairs of legs.

Adults are moths with copper-red forewings marked with two bright gray transverse bands and a wingspread of about 2 cm (3/4 inch).

Life History: This insect has a one-year life cycle. Adult moths emerge from the soil in April and early May and fly in search of suitable hosts. Females deposit eggs on terminal shoots and upper-whorl lateral shoots

Larvae hatch shortly thereafter and mine the pith of the expanding shoot. Usually only one larva is found per shoot. Larvae reach maturity by July and vacate the shoot to pupate in the soil, where they overwinter. Trees with the best growth are frequently infested.

Effects: The primary effect of the western pineshoot borer is reduction of height growth. Infested leaders are about 25 percent shorter than uninfested leaders. A tree may be attacked for several years in succession. Occasionally, a tree will form a double leader in response to the death or shortening of the infested leader. Frequently, lateral shoots overtop affected shoots and a crook or a fork results. In some plantations it is common to find well over half of the trees infested. Pineshoot borer populations tend to stabilize so that the rate of new infestations will be fairly constant from year to year in a given area.

Similar Insects: See pine tip moths.

Management Strategies: Thinning infested stands appears to concentrate shoot borers into residual trees and is therefore not recommended as a control. Uneven-aged stand management may result in less damage since fewer trees are susceptible at any one time. In plantations and seed orchards, populations can be reduced by applying sex attractant pheromones in a mating disruption or attract and kill strategy. Mating disruption is accomplished by inundated an area with pheromone during the spring, causing males to become disoriented and reducing their likelihood of successfully mating with females. In the other method, a sticky droplet containing pheromone and a pesticide is applied to foliage to attract and kill male moths.

References

Mitchell, R.G., and Sower, L.L. 1988. Phenology and heat accumulation as field guides for the seasonal history of the western pine shoot borer (Lepidoptera: Olethreutidae). J. Econ. Entomol. 81(1):286-289.

Sartwell, C., Daterman, G.E., Overhulser D.L., and Sower, L.L. 1983. Mating disruption of western pine shoot borer (Lepidoptera: Tortricidae) with widely spaced releasers of synthetic pheromone. J. Econ. Entomol. 76:1148-1151.

Sower, L.L, Daterman, G.E., and Sartwell, C. 1984. Surveying populations of western pine shoot borers (Lepidoptera: Olethreutidae). J. Econ. Entomol. 77:715-719.

Sower, L.L. and Shorb, M.D. 1984. Effect of western pine shoot borer (Lepidoptera: Olethreutidae) on vertical growth of ponderosa pine. J. Econ. Entomol. 77:932-935.

Stoszek, K.J. 1973. Damage to ponderosa pine plantations by the western pine-shoot borer. J. For. 71:701-705.

Pine Needle Sheathminer (*Zelleria haimbachi*)

Hosts: Ponderosa, Jeffrey, lodgepole, and other 2- and 3-needle pines

Distribution in California: Throughout the forests of California

Pine needle-sheath miner defoliation showing damaged branch tips, with brown, killed needles

Photo: Don Owen

Identification: The first significant evidence of infestation is the fading of developing needles in the spring. The proportion of needles affected depends on the level of infestation. Light silken webbing can also be seen around the bases of needles. This webbing contains small feeding larvae. Needles are attacked throughout their development; the shorter ones cease growing and begin to fade, while the longer ones droop sharply at the sheath. Damage is restricted to the current year's needles. A small hole is present in the sheath of each damaged needle fascicle. Damaged needles are easily removed from the fascicle. Heavy feeding will result in severe needle loss.

Adult moths are very small and silvery white. Their forewings are light yellow, each with a longitudinal white band through the center of the wing. Larvae in the needle-mining stage are tiny, threadlike, and difficult to detect. Their mines are barely visible.

Larvae that have left their mines are initially tan and become tan and green by maturity.

Feeding holes at base of needle sheath indicative of pine needle sheath-miner

Photo: Don Owen

Life History: Adults are present between mid-June and mid-August. Females lay eggs singly on the current year's foliage in mid-summer. Newly hatched larvae bore directly into the needle. Larvae mine within the needles for the duration of the summer and remain in the mined needles through winter. In the spring, the larvae emerge from the needle mines and begin feeding at the base of newly developing needle fascicles. A hole is made through the fascicle sheath and the larvae consume the bases of the needles. One larva may feed on as many as 10 fascicles before it matures. Pupae are formed in the mass of silken webbing around the needle bases and the new adults emerge about 10 days later.

Effects: Heavy feeding will cause the loss of the current year's needles. Repeated defoliation for several years can result in reduced growth and, possibly, tip dieback. The insect generally affects younger trees.

Management Strategies: Thinning will increase tree vigor and will reduce the effects of defoliation. In high-value settings such as seed orchards, the application of insecticides may be justified. Several materials are available, either as foliar sprays or systemic injections. These include esfenvalerate (e.g., Asana), acephate (e.g., Orthene), malathion, and oxydemeton methyl (also known as metasystox-r). To be effective, insecticides must be applied when trees are just beginning their current year's growth in the spring.

References

Stevens, R.E. 1971. Pine needle-sheath miner. USDA Forest Service, Forest Pest Leaflet 65. 5 p.

Ponderosa Pine Tip Moth (*Rhyacionia zozana*)

Hosts: All pine species

Distribution in California: Throughout the pine forests of California. It is most commonly associated with new plantings or grafted leaders. It rarely causes damage in trees that are well-established or more than 2 m (6 feet) tall.

Pine terminal killed by pine tip moth; note the resin at the attack site near the bud and the exit hole produced by the larva as it left the terminal to pupate in the duff

Photo: John Guyon

Adult ponderosa pine tip moth

Photo: Don Owen

Cocoons of ponderosa pine tip moth in the duff at the base of young ponderosa pine.

Photo: Don Owen

Identification: Fading of current-year foliage on affected shoots is the first sign of infestation. Foliage fades to yellow and eventually brown. Normal needle development is retarded by larval feeding. Heavily damaged shoots die, becoming dry, brittle and riddled with larval feeding tunnels. They are easily broken off. Pitch, webbing, and insect frass may also be present around the area of activity on the shoot. Near ground line on affected trees, silken, resinous cocoons are found beneath bark scales. Adults are small moths with forewings irregularly banded in gray and white on the inner two-thirds, and brick red on the outer third. Larvae are orange/brown with some rose-colored tones and have distinct legs and dark brown head capsules.

Life History: The tip moth has a one-year life cycle. Adult moths appear in April and May. Oviposition coincides with the slowing of shoot elongation and emergence of new needles. Eggs are laid on new shoots and larvae begin feeding on each shoot at the base of a needle sheath. Larvae initially feed externally and then bore into the shoot, where they mine out the pith and wood. A single shoot may contain several larvae. Mining occurs in spring and early summer, and often kills the shoot. Both lateral and terminal shoots are attacked. . Mature larvae stop feeding about mid summer and most crawl to the ground to form cocoons at the base of the tree. An occasional larva pupates in the dead shoot. Winter is passed in the pupal stage.

Effects: Larvae mine in the phloem and xylem of lateral and terminal shoots. Small trees are most susceptible. New shoots are killed by the attacks. Repeated attacks slow growth and cause crooks, forks, and multiple stems. Tip moths rarely kill established trees outright, but attacks can affect survival of young planted seedlings. Infested trees usually outgrow the damage.

Similar Insects: Damage from the pine needle sheath miner superficially looks similar – i.e. shoots with short, fading needles. Close inspection easily separates the damage.

Management Strategies: Management action is generally unnecessary since most infested trees overcome tipmoth damage.

References

Stevens, R.E. 1966. The ponderosa pine tip moth, Rhyacionia zozana, in California. (Lepidoptera: Olethreutidae). Ann. Ent. Soc. Amer. 59(1):186-192.

Stevens, R.E. 1971. Ponderosa pine tip moth. USDA Forest Service, Forest Pest Leaflet 103. 5 p.

Gouty Pitch Midge (*Cecidomyia piniinopsis*)

Hosts: Ponderosa pine

Distribution in California: Throughout the range of ponderosa pine

Gouty pitch midge magotts withing swellings

Photo: Scott Tunnock

Identification: Most damage is first noticed in the spring when tufts of the previous year's needles fade to yellow and eventually reddish brown. This dieback occurs at the end of the midge's one-year life cycle. From summer through winter, small, salmon-colored larvae are found in pitch pockets in the cortical tissue of infested, green shoots. Larvae exit from infested shoots in the early spring, but it is usually possible to cut into a faded shoot and find some larvae that failed to emerge. Pupal cases of the midge are attached to needles. Light infestations may cause little damage other than minor distortion of the bark around the pitch pocket., Heavy infestations can girdle and kill the shoots. On some trees, nearly every new shoot is affected. If there are not enough larvae to kill a shoot, the injury may produce scarring that eventually heals over. Affected trees appear to have genetic susceptibility to pitch midge, therefore attacks can be scattered in plantations. Attacks are typically heaviest on trees with sticky twigs and lightest on trees with dry, powdery twigs.

Gouty pitch midge in poderosa pine

Photo: Danny Cluck

Life History: Adult midges are minute flies resembling mosquitoes. They fly in the spring, at which time the females lay minute red eggs on new shoots. On hatching, the larvae bore into the shoots and form small cavities in the growing tissues. The surface of the shoot will show a swelling over each cavity. The larvae live in the pitch-filled cavities through the year, reaching maturity in late winter. In early spring the pitch pockets erupt and the larvae crawl out onto the needles to pupate in cocoons the size of a grain of rice. In 2 to 3 weeks the new adults emerge. There is a single generation per year.

Cocoons of gouty pitch midge on ponderosa pine.

Photo: Don Owen

Effects: Heavy infestations cause branches to die and reduce the growth rate of affected trees. When terminal shoots are killed, crooks or forks can result. Chronically infested trees become gnarled and stunted.

Similar Insects: Most other insects and diseases that kill shoots will do so before the shoots and needles have fully developed. Shoots infested by the gouty pitch midge typically do not die until the following year.

Management Strategies: Vigorous, rapidly growing trees tolerate infestation without shoot deformation or mortality. Elimination of competing vegetation and proper matching of planting site and seed source in plantations will result in vigorous trees that tolerate Gouty Pitch Midge infestations without serious damage. While it may be possible to select for and plant resistant stock, this has not been tried.

Reference

Eaton, CB and JS Yuill. 1971. Gouty Pitch Midge. USDA Forest Service For. Pest Lflt. 46. 8p.

Table 13. Common Insects found on Tree Regeneration

Common Insects Found on Tree Regeneration

Name	Hosts	Tree Size	Damage	Field I.D.	Prevent/Control	Notes
Cambium Feeders						
Pine Engravers *Ips* spp.	Ponderosa, Jeffrey, sugar, lodgepole and coulter pines	Sapling, pole	Tree killing, top killing	Tuning fork gallery	Slash disposal or treatment, brush control, thinning	Many spp., will breed in slash
Fir Engraver *Scolytus ventralis*	White and red fir	Sapling, pole	Tree killing, top killing	Horizontal gallery	Slash disposal, thinning	Will breed in slash
Douglas-fir Engraver *Scolytus unispinosus*	Douglas-fir	Sapling, pole	Tree killing, top killing	Vertical gallery	Slash disposal, thinning	Will breed in slash
Pine Repro. Weevil *Cylindrocopturus eatoni*	Ponderosa, Jeffrey and sugar pine	Seedling, sapling	Tree killing, top killing	Needle feeding, pupal chambers	Brush and grass control	Usually on poor sites
Douglas-fir Repro. Weevil *Cylindrocopturus furnissi*	Douglas-fir	Seedling, sapling	Tree killing, top killing	Pupal chambers	Brush and grass control	
Gouty Pitch Midge *Cecidomyia piniinopis*	Ponderosa and Jeffrey pine	Seedling, sapling	Twig death, deformity	Pink larvae, pitch pockets	Maintain tree vigor	Very common in some years
Defoliators						
Needle Sheath Miner *Zelleria haimbachi*	Ponderosa, Jeffrey and lodgepole pine	Seedling, sapling, pole	Defoliation, growth loss?	Hole in needle sheath	Maintain tree vigor	outbreaks usually of limited duration

Common Insects Found On Tree Regeneration (Continued)

Name	Hosts	Tree Size	Damage	Field I.D.	Prevent/Control	Notes
Defoliators						
Doug. fir Needle Midge *Contarinia* spp.	Douglas-fir	Seedling, sapling, pole	Needle discoloration, defoliation, twig death	Discolored, needle gall		3 spp., very common some years
Grasshoppers	All species	Seedling, sapling	Debarking, defoliation	Indiscriminant feeding	Avoid grassy sites, pesticides	Common on re-planted burns
Scales						
Pine Needle *Chionaspis pinifoliae*	All pines, Douglas-fir and Incense cedar	Seedling, sapling, pole	Growth reduction?	Elongated white scale	Reduce dust, and pesticide use	Assoc with fumes, dust, smog, and spray drift. Old scales not removed by insecticides
Black Pine Leaf *Nuculaspis calilfornica*	Douglas-fir, Ponderosa, Jeffrey, sugar, Monterey and gray pine	Seedling, sapling, pole	Sparse foliage, growth reduction, mortality	Black oval scale	See above	See above
Cooley Spruce Gall Aphid *Adelges cooleyi*	Douglas-fir, all spruces	Seedling, sapling, pole	Needle discoloration, twisted needles, defoliation	White “wooly aphid” on DF	Pesticides	Galls formed on spruces, serious only to DF seedlings
Shoot Borers And Tip Moth						
Western Pineshoot Borer *Eucosma sonomana*	Jeffrey and ponderosa pine	Seedling, sapling, pole	Short leaders, forking	Short leaders, short clumped needles	Pheromone-based treatment	Damage seen on east side sites only
Ponderosa Pine Tip Moth *Rhyacionia zozana*	Ponderosa, sugar and gray pine	Seedling, sapling	Leader and shoot mortality	Reddish brown larvae, Shoots	Maintain tree vigor	

Cone and Seed Insects

Insects that destroy the seeds of forest trees have an important bearing on reforestation, regardless of whether the seeds are in natural areas or seed orchards. Cone and seed insects include representatives from a number of orders and families of insects. Included are various species of beetles, borers, moths, maggots, chalcids, and true bugs. These cause the destruction of seeds by attacks on buds, flowers, immature and mature cones, as well as the seeds themselves.

Effects: In the natural forests the impact of cone and seed insects is quite variable. Most tree species produce heavy seed crops periodically, the heavy crops being interspersed by years when seed production is light. This periodic production appears to have a profound effect upon insect populations that feed upon seeds and cones. When their food is scarce, the insect populations decline and when a bumper cone crop occurs, the number of seed eaters present is too low to destroy a large proportion of the seeds. However, periodically there are two successive "seed years." When this happens, the seed insects may build up to high numbers during the first seed year so that the crop produced the following season may be almost completely destroyed. The variation between the number and size of trees, acres, terrain, and seed years makes management of cone and seed insects in natural forests difficult and relatively uneconomical and therefore, little effort has been made to reduce their impacts.

The most effective efforts at seed production are in the improvement of tree varieties by selecting and breeding elite individuals either in seed production areas or seed orchards. Seed orchards lend themselves to integrated pest management and it is here that the greatest impacts can occur. Increase in sound seed from seed production areas and seed orchards is being accomplished through prevention practices, direct control using chemicals and an integrated approach using several methods.

Management Strategies: Prevention methods include: 1) the establishment of seed orchards remote from, rather than adjacent to, natural stands of the same species – in this way they are less likely to be infested by insects that occur in natural stands; 2) delay the flowering time of trees by spraying with cold water or other methods – most of the major seed-destroying insects lay their eggs in the spring when flowers of the host are being pollinated, and trees that flower earlier or later than normal are less susceptible to attack; 3) annual removal of all cones from orchard areas may ensure that most harmful insects are removed and thus reduces the likelihood of severe attack the following year; and 4) utilizing protective screen bags around flowers or cones to increase the sound seed yield per cone.

Seed losses to insects in seed orchards or seed production areas can also be reduced with insecticides if preventative measures do not prove satisfactory. To date, best results have been achieved by applying systemic insecticides as granules or liquid around the base of each tree, foliar sprays, or injections into the trunk.

The use of synthetic pheromones, or attractants, and blacklight trapping may also reduce insect populations.

Western Conifer Seed Bug (*Leptoglossus occidentalis*)

Hosts: Common on knobcone, Monterey, ponderosa, sugar and western white pines as well as Douglas-Fir.

Distribution in California: Statewide, including non-forested regions.

Identification: A large sucking bug with the outline of a white diamond on each wing; a strong flyer that flashes the orange on its back when it takes off. Adults are about 1.3 to 1.9 cm long and 0.6 cm wide. Nymphs are similar to adults but are smaller and lack developed wings. Both adults and nymphs like to "sun" on flower rosettes. When disturbed, the adults fly away and omit a musty odor; nymphs retreat into the spaces between the cones and the branch to which they are attached.

Western conifer-seed bug

Photo: Whitney Cranshaw

Effects: Seeds are sunken and/or withered if damage occurs before the seed coat hardens; normal appearing but hollow except for a wafer of endosperm tissue if damage occurs after the seed coat hardens. These insects can destroy substantial quantities of seed. Losses are difficult to estimate because there are other causes of empty seed.

Life History: The western conifer seed bug produces a single generation each season. Adults emerge from overwintering sites by mid-May and feed on inflorescences and one year-old cones. Eggs laid on host conifers hatch in 10 days, and first instar nymphs feed on needles and tender tissue of cone scales. Later, nymphs use their piercing-sucking mouthparts to feed on developing seeds. Nymphs in all five stages of development and new adults can be observed feeding on the same group of cones by mid-August, at which time the nymphs begin to reach adulthood. Adults feed on ripening seeds until early fall and then seek overwintering sites under pine bark or other protected areas. At the onset of cold weather, adult western conifer seed bugs may also enter buildings in search of protected overwintering sites.

Similar Insects: *Leptoglossus zonatus* feeds on juniper berries. The body of this species is narrower and has a faint yellow band rather than a white diamond pattern on the wings. Other species of *Leptoglossus* are pests of fruit and nut crops in agricultural regions.

Management Strategies: Both contact and systemic insecticides have been used to protect pine seed crops in the Southeast. In seed orchards, burning or removal brush piles, stacks of lumber, or other protected locations where adults find winter shelter may reduce survival. Plastic mesh bags over cones will exclude the insects.

References

Hedlin, A.F.; Yates, H.O. III; Cibrian-Tovar, D.; Ebel, B.H.; Koerber, T.W.; Merkel, E.P. 1981. Cone and seed insects of North American conifers. Canadian Forestry Service, United States Forest Service, Secretaria de Agricultura y Recursos Hidraulicos, Mexico. 122 p.

Koerber, T. W. 1963. *Leptoglossus occidentalis* (Hemiptera: Coreidae): A newly discovered pest of coniferous seed. *Ann. Entomol. Soc. Amer.*, 56:229-234.

Schowalter T. D., and Sexton J. M. 1990. Effect of *Leptoglossus occidentalis* (Heteroptera: Coreidae) on seed development of Douglas-fir at different times during the growing season in western Oregon. *J. Econ. Entomol.* 83:1485–1486.

Cone Beetles (*Conophthorus* spp.)

Hosts: Most pines

Distribution in California: Throughout the forested regions of California.

Identification: Adult beetles are reddish brown to black, shiny bark beetles. External evidence consists of pitch tubes at the point of entry on the cone stalk or the base of the cone. Following attack, cones turn brown and wither. If beetles have emerged, small round exit holes may be found on the outside of affected cones. Inside, beetles leave cones riddled with tunnels and frass.

Cone beetle

Photo: James Hanson

Effects: These beetles cause the death of second-year cones. The amount of mortality is highly variable but in some years a large proportion of cones may be attacked.

Life History: One generation is produced per year. Adult beetles bore into the base or stem of immature second-year cones in the spring. A gallery is created along the cone axis, with eggs deposited along its sides. The creation of the gallery severs the conductive tissues of the cone, killing it. Larvae hatch and feed on the scales, seeds, and tissues of the cone. The brood complete development during the summer within the cone, and usually overwinter there. Some new adults emerge and may bore into shoots or conelets and overwinter.

Similar Insects: This insect is best distinguished from other insects that attack developing cones by the presence of the pitch tube on the cone base or stem.

Management Strategies: In seed orchards, cleaning up and removing aborted, infested cones reduces populations. Applications of insecticides can provide protection to cone crops. Single and multiple applications of the insecticide, permethrin, applied to second year conelets in a western white pine seed orchard significantly reduced loss of cones to cone beetles (Shea et al. 1983). Burning of fallen cones may reduce populations and reduce infestations of the next cone crop.

References

Furniss, M.M. 1997. *Conophthorus ponderosae* (Coleoptera: Scolytidae) infesting lodgepole pine cones in Idaho. Envir. Entomol. 26(4): 855-858.

Hedlin, A.F.; Yates, H.O. III; Cibrian-Tovar, D.; Ebel, B.H.; Koerber, T.W.; Merkel, E.P. 1981. Cone and seed insects of North American conifers. Canadian Forestry Service, United States Forest Service, Secretaria de Agricultura y Recursos Hidraulicos, Mexico. 122 p.

Miller, W.E. 1978. Use of prescribed burning in seed production areas to control red pine cone beetle. *Environ. Entomol.* 7: 698-702.

Shea, P.J., Jenkins, M.J., and Haverty, M.I. 1983. Cones of blister rust-resistant western white pine protected from *Conophthorus ponderosae* Hopkins (=C. monticolae Hopkins) *J. Georgia Entomol. Soc.* 19(1): 129-138.

Douglas-fir Cone Moth (*Barbara colfaxiana*)

Hosts: Douglas-fir

Distribution in California: Sierra Nevada and Cascade Mountains and Coastal Range. More common inland than on the coast.

Identification: The adult is a small moth (wingspan 15-20 mm) with greyish-brown speckled forewings. The yellowish-white larva is an active feeder, often leaving clusters of frass on the cone as external evidence of its presence. Large cones, usually found in coastal areas, may present no external evidence of damage. Surface pitch cannot be relied on to indicate the presence of this insect.

Douglas-fir cone moth larvae

Photo: Julie Brooks

Effects: One of the most serious pests of Douglas-fir cones as a single larva will destroy much of the seed in a cone; and two to three will destroy 100% of the seed. This insect is probably more of a pest in coastal Douglas-fir than Cascade and Sierran Douglas-fir.

Life History: Eggs are laid on flowers in early spring. Young larvae begin feeding on scale tissue, but feed more on seeds as they mature. By the end of July, they pupate in a tough, pitch-coated cocoon in the center of the cone. Pupae may remain in diapause for 1-3 years in old cones after they have fallen from the trees.

Similar Insects: Other species of *Barbara* with identical life cycles and habits are found in the cones of true firs and one species is found in Douglas-fir (*B. ulteriorana*). At least two species of *Dioryctria* also feed in Douglas-fir cones. The larvae of these moths are reddish brown.

Management Strategies: Years with abundant cone crops suffer little damage, whereas nearly all the seed in a light cone crop will be destroyed. Systemic insecticides have been used to protect cone crops in orchards.

References

Hedlin, A.F.; Yates, H.O. III; Cibrian-Tovar, D.; Ebel, B.H.; Koerber, T.W.; Merkel, E.P. 1981. Cone and seed insects of North American conifers. Canadian Forestry Service, United States Forest Service, Secretaria de Agricultura y Recursos Hidraulicos, Mexico. 122 p.

Pine Coneworm (*Dioryctria auranticella*)

Hosts: Ponderosa pine

Distribution in California: Statewide in suitable hosts.

Pine coneworm damage
Photo: Whitney Cranshaw

Identification: Adults are reddish-tan moths. Entire cones are usually killed by pine coneworms; partially killed cones become distorted and do not open. Larval feeding cavities inside cones are filled with frass and webbing.

Effects: Larvae bore large, meandering, circular tunnels through young cones. Two or more larvae can destroy much of the seed in a cone. Pupation and overwintering usually occur in the cone.

Life History: Life history is variable and not well known. Larvae develop from June through September in new growing cones. Some larvae pupate in cocoons on the ground during July, August and September and adults emerge shortly after to lay eggs, which overwinter. Other larvae overwinter as prepupae in cocoons in the ground or in cones, pupate in the spring and emerge as adults during May and June. Eggs are laid on twigs and cone bracts.

Similar Insects: There are a variety of cone and seed feeding insects. Other species of insects that feed in seeds and cones of ponderosa pine in California include pine seed chalcid (*Megastigmus albifrons*), ponderosa pine cone beetle (*Conophthorus ponderosae*), and the pine seed worm (*Cydia piperana*). This conophyte is distinguished by the entry hole in the basal portion of the cone and larval feeding cavities filled with frass and webbing.

Management Strategies: Insecticides have proven effective in managing coneworm populations in western white pine seed orchards. Pheromones have been identified for monitoring and possibly mating disruption and trap out strategies in seed orchards.

References

Blake, E. A., M. R. Wagner, and T. W. Koerber. 1985. Insects destructive to the ponderosa pine cone crops in northern Arizona. In: Proc. Conifer Tree Seed in the Inland Mountain West Symposium, Aug. 5-6, Missoula, MT. USDA Forest Service, Intermountain Research Station: 238-242.

Hedlin, A.F.; Yates, H.O. III; Cibrian-Tovar, D.; Ebel, B.H.; Koerber, T.W.; Merkel, E.P. 1981. Cone and seed insects of North American conifers. Canadian Forestry Service, United States Forest Service, Secretaria de Agricultura y Recursos Hidraulicos, Mexico. 122 p.

Pine Seedworm (*Cydia piperana*)

Host: Ponderosa and Jeffrey pine

Distribution in California: Throughout the range of ponderosa and Jeffrey pine.

Identification: Adult moths have a wingspan of 10 to 20 mm. The fore wings are metallic gray with silver bands. Larvae are 10 to 15 mm when mature, white to cream colored, and have a mottled head capsule. There is no external evidence of infestation. Inside the cones, frass and mining can be seen in the cone axis. Seed pairs on the same scales can become fused together by the silk-lined tunnels produced by larvae. These seeds often stick to the scales and remain in the cones.

Effects: In some years this insect can consume a large proportion of the seed crop.

Life History: One generation is produced annually. Eggs are laid at the base of cone scales, on the surface of the scale, or on the cone stalk. Newly hatched larvae bore between the cone scales, enter a seed, consume it, and leave it filled with frass. It then moves on to another seed, leaving a silk lined trail. As the larva matures, it burrows into the cone axis and overwinters. In spring, the insect pupates. Following pupation, the adult emerges.

Similar Insects: There are a variety of cone and seed feeding insects. Other species of insects that feed in seeds and cones of ponderosa pine in California include pine seed chalcid (*Megastigmus albifrons*), ponderosa pine cone beetle (*Conophthorus ponderosae*), and the ponderosa pine cone moth (*Dioryctria auranticella*).This insect is distinguished by the presence of the frass-packed seeds and larvae or mining in the cone axis.

Management Strategies: Insecticide applications have been used to control similar species in the southeastern United States. Collecting and burning cones containing overwintering larvae might reduce infestations in the following year in isolated seed orchards.

References

Hedlin, A. F. 1967. The Pine Seedworm, *Laspeyresia piperana* (Lepitoptera: Olethreutidae), in cones of ponderosa pine. *The Canadian Entomologist* 99:264-67.

Hedlin, A.F.; Yates, H.O. III; Cibrian-Tovar, D.; Ebel, B.H.; Koerber, T.W.; Merkel, E.P.

1981. Cone and seed insects of North American conifers. Canadian Forestry Service, United States Forest Service, Secretaria de Agricultura y Recursos Hidraulicos, Mexico. 122 p.

Douglas-fir Seed Chalcid (*Megastigmus spermotrophus*)

Hosts: Big Cone Douglas-fir and Douglas-fir

Distribution in California: Throughout the range of Douglas-fir

Douglas-fir seed chalcid
Photo: Cheryl Moorehead

Identification: Adults are yellow, ant sized wasps with clear wings. There is no external evidence of damage until adults emerge. Dissection or x-rays of extracted seed is required to detect damage. Look for maggot-like larvae inside the seeds. They are approximately 2 mm long and creamy white.

Effects: Larvae feed inside seeds. Heaviest damage usually occurs when the cone crop is light because this often is when the percentage of seeds attacked is greatest.

Life History: Female wasps lay eggs in seeds in immature cones that are 2 to 3 weeks old. Susceptible cones are from 1 to 3 inches long. Younger or older cones are usually not attacked. Eggs are laid directly into developing seeds, normally one egg per seed. Larvae overwinter inside seeds on the forest floor. They pupate in early spring within seeds and emerge during May into June.

Similar Insects: Other species of seed chalcids with habits and life cycles very similar to the Douglas-fir seed chalcid infest the seed crops of true firs, western hemlock and ponderosa pine.

Management Strategies: Insecticides are currently available for control of many cone and seed insects on Douglas-fir.

References

Niwa, C. G. & D. L. Overhulser. 1992. Oviposition and development of *Megastigmus spermotrophus* in unfertilized Douglas-fir seed. *J. Econ. Entomol*. 85: 2323-2328.

Sandquist, R. and K. Sprengel. 1994. How to monitor chalcids in Douglas-fir seed orchards. USDA Forest Service, Pacific Northwest Region Natural Resources. R6-FPM-UP-008-94.

Schowalter, T.D.; Haverty, M.I.; Koerber T.W. 1985. Cone and seed insects in Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, seed orchards in the western United States: distribution and relative impact. *Canadian Entomologist* 117: 1223-1230.

Nursery Insects

Seedlings in forest nurseries, whether grown in containers or as bare roots, are susceptible to a number of insects that attack the roots, stems, and leaves. These insects are able to inflict more injury at this stage than later when the trees have developed larger root, stem, and needle systems. Nurseries, like seed orchards, can have more pest problems because of the monoculture environment.

The major groups of insects infesting seedlings are weevils, white grubs, cutworms, wireworms, aphids, scales, sod webworms, beetles, earwigs, grasshoppers, thrips, and mites. Some of these insects are considered forest insects, while others are agricultural-related insects adapting themselves to a new environment. The insect problems can be quite variable between nurseries and from year to year.

Some preventative measures such as soil fumigation or treating the soil with insecticides are done on an annual or biennial basis for soil inhabiting insects. To date, most of the control measures have been the use of conventional chemicals. Nurseries like the seed orchards lend themselves to other types of insect management techniques such as blacklight trapping, pheromones, and attractants. Plowing beds and planting them to cover crops or allowing them to remain fallow for at least a year may help to reduce some insect populations. Other procedures are being developed and used to monitor insect populations in nurseries in order to take action before significant damage occurs.

Invasive Insects

Similar to the rest of the Nation, California's forests and grasslands are threatened by invasions of exotic insect species. Over the past 200 years, several thousand foreign plant and animal species have been introduced in the United States. About one in seven of these species has become invasive.

Invasive insects that are established in California and pose a threat to native forest ecosystems include the redhaired pine bark beetle, *Hylurgus ligniperda*, the Mediterranean pine engraver beetle, *Orthotomicus erosus*, the light brown apple moth, *Epiphyas postvittana*, and goldspotted oak borer, *Agrilus auroguttatus*. Invasive insects that are established in other states and have the potential to cause damage to California's forests are the emerald ash borer, *Agrilus planipennis*, the Asian longhorned beetle, *Anoplophora glabripennis*, the gypsy moth, *Lymantria dispar*, and the sirex woodwasp, *Sirex noctilio*.

The Animal and Plant Health Inspection Service is responsible for regulating the movement of plants and plant materials that may carry pest organisms, and for detection and eradication of new pest introductions. The USDA Forest Service, the Bureau of Indian Affairs, and other Federal land management agencies are responsible for reducing the impact of invasive exotic plants on lands they manage. Despite the efforts, we expect increased introductions of nonnative species, as well as accidental introductions of native species from the U.S. (from one part of the country to another), due to expansion of global and national trade. Early detection and rapid response are important to minimize invasive species establishment and subsequent resource damage.

References

Corn, M. L., E. H. Buck, J. Rawson, and E. Fischer. 1999. Harmful nonnative species: issues for Congress. National Council for Science and the Environment. Report RL30123. 50 p.

Redhaired Pine Bark Beetle (*Hylurgus ligniperda*)

Hosts: Many pine species throughout the world. In California, it has been frequently encountered in cut logs of Aleppo pine and Canary Island pine, and in green waste piles in Los Angeles County. Other known hosts in California's urban landscape include planted Monterey pine (in the Greater San Francisco Bay Area) and Italian stone pine.

Distribution in California: First detected in California in 2003. As of May 2007, the redhaired pine bark beetle (RPBB) has been collected by hand or in attractant-baited survey traps in six counties in southern California (Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura). The northern most collection point has been near the community of Castaic on the southern base of the Sawmill Liebre Mountain Range.

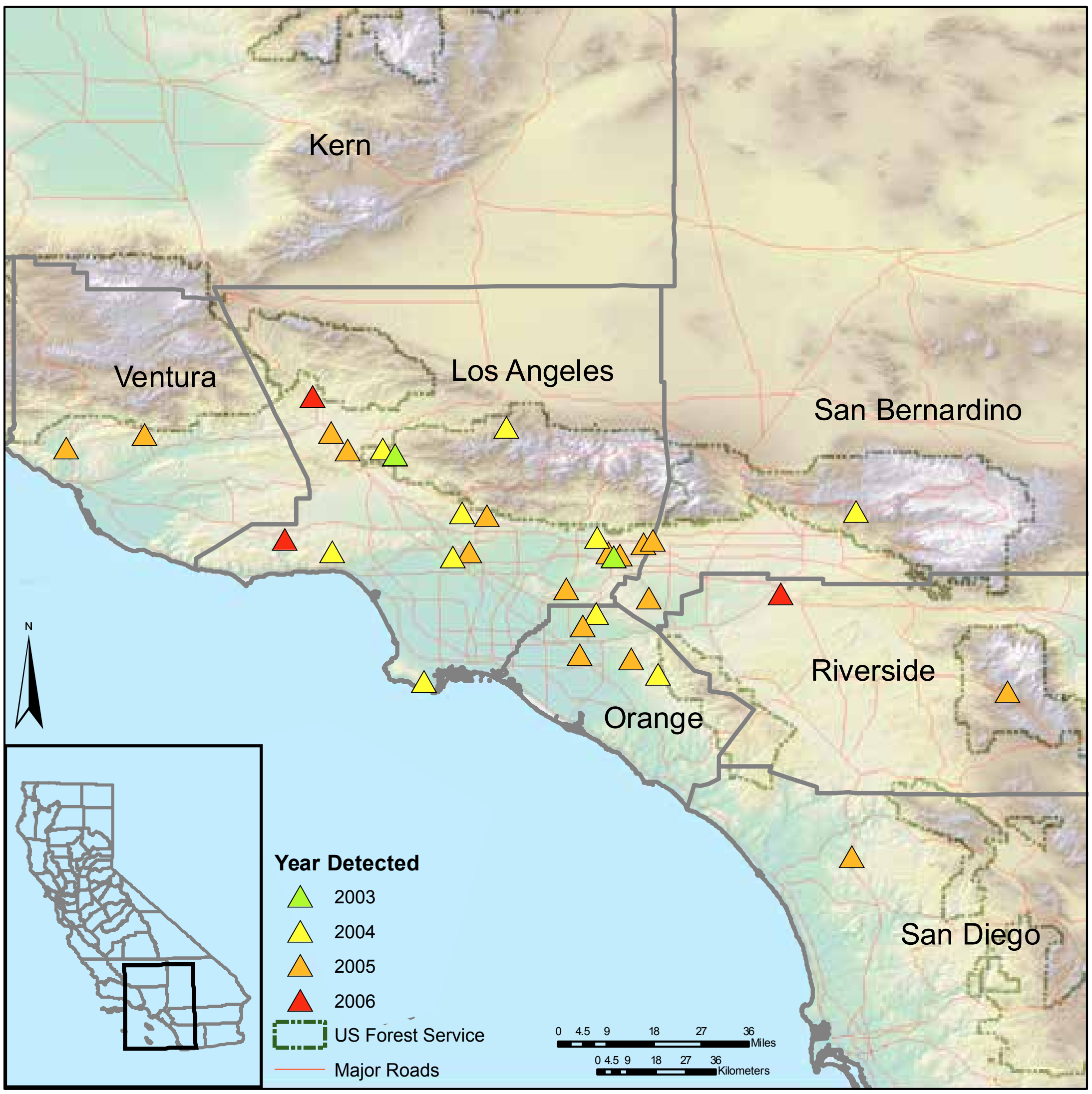


Figure 21. Detections of the red-haired pine bark beetle in southern California

Source: R.L. Penrose, J.C. Lee, D.-G. Liu, and S.J. Seybold, unpublished data

The native distribution of RPBB includes southern and central Europe, Russia, the Mediterranean region, and the nearby Atlantic Ocean islands. It has also been introduced and has established populations in Australia, Japan, New Zealand, South Africa, parts of South America (Chile, Brazil, and Uruguay), Sri Lanka, and now the U.S.

Dorsal and lateral view of the red haired pine bark beetle

Photo: K. Loeffler

Identification: Adults are relatively small black beetles about 6 mm (0.2 in) long by 2 mm (0.1 in) wide. Coarse, reddish hairs are particularly noticeable on the posterior slope of the wing covers (elytra), and the posterior margins of the elytra are smooth (lacking teeth, spines, or bumps) The beetle feeds in the phloem of the basal portion of pine stems, large roots, or woody debris on the soil surface.

Effects: RPBB has a broad host range among pines and has been reported to kill healthy trees and seedlings in locations outside the U.S. Native populations of RPBB in the Mediterranean region have damaged the exotic pines found in California for many years. Another major concern in the U.S. is that RPBB will vector black-stain root disease, *Leptographium wageneri*, a virulent native pathogen that currently threatens western conifers though a native bark beetle vector system. Since adults overwinter gregariously in galleries beneath the bark of roots, they may easily cross contaminate each other with fungal spores. RPBB is present in a wide range of climates throughout the world, so it could potentially survive in other regions of the West outside of California.

Life History: Adult RPBB are good fliers and can disperse over several kilometers in response to host volatiles. They have been observed feeding and reproducing in the phloem of large dimension logs of Aleppo pine and Canary island pine, and females prefer to colonize through surfaces of cut logs in contact with moist soil. In other locations, female RPBB have laid up to 500 eggs in their galleries. In 2006 and 2007, field observations and flight trapping data suggested that RPBB can complete at least two generations a year in southern California. Colonization by parents of the first generation has been observed from late February through mid-March. After this initial flight and period of colonization, subsequent peak flight activity was observed in early May and late July. Flight activity continues year round, but it has been variable, depending on the locality.

Similar Insects: Several species of native bark beetles are similar in appearance, habits and life cycle.

Management Strategies: Maintaining healthy trees and sanitation are the keys to preventing attacks. Infested trees or tree parts should not be moved from infested to uninfested counties; they should be removed and chipped or burned in infested areas; green pine firewood should not be stored near live trees. Topically applied insecticides (carbamates and pyrethroids) can be used to protect live trees from RPBB, but they are difficult to apply below the soil line and may have deleterious environmental impacts. Research is proceeding on the development of non-toxic behavioral repellents to protect valuable pines in urban settings. The synergistic combination of ethanol and α-pinene can be used as trap bait for early detection.

References

USDA Forest Service. 1993. Pest risk assessment of the importation of *Pinus radiata*, *Nothofagus dombeyi*, and *Laurelia philippiana* logs from Chile, pp. viii, 30-36, USDA FS Misc.

Publ. No. 1517.

Liu, D.-G., Bohne, M.J., Lee, J.C., Flint, M.L., Penrose, R.L., and Seybold, S.J. 2007. New introduction in California: The redhaired pine bark beetle, *Hylurugus ligniperda* Fabricius. USDA Forest Service, Pest Alert, R5-PR-07, November, 2007, 3 pp.

USDA APHIS. 2000. Pest risk assessment for importation of solid wood packing materials into the United States: Bark beetles, pp 183-185, Raleigh, North Carolina.

Mediterranean Pine Engraver Beetle (*Orthotomicus erosus*)

Hosts: In western U.S.: Afghan, Aleppo, Canary Island, Coulter, Italian stone, Monterey, and Turkish pine. In eastern U.S.: Eastern white, Scots, shortleaf, and slash pine.

Distribution in California: First detected in California in 2003, the beetle has been found in flight traps in five counties in California's southern Central Valley. In Fresno, Tulare and Kern counties, abundant overwintering populations of larvae, pupae, and adults have been found in cut logs of Aleppo pine and Italian stone pine. The Mediterranean pine engraver beetle has so far been detected in urban locations, particularly parks, golf courses, and green waste recycling facilities.

The native range of this beetle is the Mediterranean, the Middle East, Central Asia, and China. It has been introduced into Chile, England, Fiji, Finland, South Africa, Swaziland, and Sweden.

Adult Mediterranean pine engraver beetle

Photo: Louis-Michel Nageleisen

Identification: Adult beetles are approximately 2.7 to 3.5 mm (0.11 to 0.13 in) in length and reddish brown. Mediterranean pine engraver adults can be distinguished from other small bark beetles by a moderately concave declivity on the end of the abdomen bearing four spines on each side, similar to pine engravers. The second spine is the broadest of the four. For further details on identification, refer to the web-based "Screening Aid" in sources. Adult males have more pronounced spines than females. They can be found in galleries on the inside of bark. Parent galleries often have two branches, sometimes three. These egg galleries comprise the central tunnel; each is approximately ½ to 5 inches long with numerous larval tunnels extending outwards.

Effects: Mediterranean pine engraver adults generally behave as secondary pests. They are most likely to infest recently fallen trees, standing trees that are under stress, logging debris, and broken branches with rough bark that are at least two inches in diameter. Healthy trees have rarely been attacked. In Israel, beetles are often found on the main stem and larger branches of stressed trees that are over 5 years old. In California, this species, or evidence of its past activity, has been found in cut logs from 6 inches to 3 feet in diameter, on stumps from 4 inches to 3 feet in diameter, on declining branches of live standing trees, and on the main stem of dead standing trees. Besides direct feeding on phloem, this beetle also may vector pathogenic fungi that further weaken pine trees. The beetle may carry spores of fungal pathogens already present in the U.S. or other unknown pathogens from other areas of its native or introduced range.

Life History: Observations in the Central Valley of California indicate that this species overwinters as larvae, pupae and adults beneath the bark surface. Overwintered adult beetles start flying in late February and establish brood galleries by mid-March. Flight of parent and new adults continues until October or November. In Israel, adults start brood production in early March and require a period of feeding before reaching sexual maturation. New adults may re-infest the same host material that they emerged from or may attack new material. This species has two generations per year in Turkey, France and Morocco; 3-4 generations in

Tunisia and South Africa; and 3-5 generations in Israel where adults are active from March to October. In California, the number of generations per year is not yet known.

Similar Insects: Native species of engraver beetles such as *Ips* spp. Within its current range in California, Mediterranean pine engraver adults can be distinguished from other small bark beetles by a moderately concave declivity on the end of the abdomen bearing four spines on each side.

Management Strategies: Prevention is the key to managing Mediterranean pine engraver. This involves good sanitation, limiting movement of recently cut pine branches and stems, keeping standing trees healthy and early detection of infestations. Populations can build up when freshly cut, broken, or dead logs/branches are available. The following good sanitation practices are recommended: 1) avoid piling any pine material next to live trees; 2) chip, burn or debark freshly cut pine material; or 3) for small quantities of pine material, completely cover material with thick, clear plastic sheeting in a sunny location. Beetle populations can spread quickly if infested pine logs are transported. Thus, moving firewood is undesirable. Proper care and watering of standing trees can reduce the probability of an outbreak since beetles have been only observed to attack living trees under drought or fire stress. Early detection of the Mediterranean pine engraver will enable people in affected areas to institute prevention measures. Funnel traps baited with α-pinene, methylbutenol, ipsdienol, and ethanol are effective at catching flying adults. Research is proceeding to improve this attractant and to discover repellent semiochemicals to protect standing trees.

References

Cavey, J., Passoa, S. and Kucera D. 1994, Screening Aids for Exotic Bark Beetles in the Northeastern United States. NA-TP-11-94. Northeastern Area: U.S. Department of Agriculture, Forest Service.

Eglitis A.E. 2000. Mediterranean pine engraver beetle. USDA Animal and Plant Health Inspection Service and Forest Service Pest risk assessment for importation of solid wood packing materials into the United States, pp 190-193.

Haack R.A. 2001. Intercepted Scolytidae (Coleoptera) at U.S. ports of entry: 1985-2000. Integrated Pest Management Reviews 6: 253-282.

Mendel, Z. 1983. Seasonal history of *Orthotomicus erosus* (Coleoptera: Scolytidae) in Israel. Phytoparasitica 11:13-24.

Orthotomicus erosus (Wollaston) Screening Aid. Bark Beetles of North America Image and Fact Sheet Library. http://www.barkbeetles.org/exotic/oreross.html

Tribe, G.D. 1990. Phenology of *Pinus radiata* log colonization and reproduction by the European bark beetle *Orthotomicus erosus* (Wollaston) (Coleoptera: Scolytidae) in the south-western Cape Province. J. Entomological Society of South Africa 53:117-126.

Wood, S.L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae) a taxonomic monograph. Great Basin Naturalist Memoirs. Brigham Young University, Provo, UT. 1359p.

Goldspotted Oak Borer (*Agrilus auroguttatus*)

Hosts: In California: coast live, canyon live, and California black oak.

Distribution in California: The goldspotted oak borer was first detected in California in 2004 by an exotic woodboring survey, but was not linked with oak mortality until 2008 in San Diego County. The known distribution is limited to San Diego and Riverside Counties around the Descanso Ranger District, Cleveland National Forest, and San Jacinto Ranger District, San Bernardino National Forest. The oak borer has been confirmed injuring oaks on public, private, county, tribal, and state lands.

The native range of this beetle is in southeastern Arizona; and southern Baja California, Mexico. It is hypothesized to have been introduced on firewood from Arizona.

Goldspotted oak borer adult

Photo: Tom Coleman

Identification: Adult beetles are approximately 2.0 to 1.8 mm (0.08 to 0.07 in) in length and a dark green with six circular patches of golden-yellow pubescence on the forewings. Additional golden-yellow coloring is found on the dorsal edges of the prothorax and sides of the abdomen. The adults are distinguishable from other woodborers by the six characteristic orange spots on the forewings. Adults are rarely seen, but may be seen resting on foliage in the canopy or on the main stem. Mature larvae are approx. 13/16 inch (2 cm) in length and white in color. Larvae are legless and tapered in shape with pincher-like spines at the tip of the abdomen. Larvae can be identified to genus by examining the C-shaped spiracles and pincher-like spines. Mature larvae are commonly found in the outer bark during the spring/early summer and late fall in pre-pupal behavior.

Effects: The goldspotted oak borer can aggressively attack oaks. Larvae feed in the cambial region on the main stem and larger diameter branches. Galleries are meandering in shape and are typically dark in color when the bark is freshly removed. Extensive larval feeding can kill patches of the cambium. These areas can be recognized by wet, black staining or red bleeding on the outer bark. Staining and bleeding can occur from the root collar and extend upward to larger branches. Repeated attacks on the main stem over several years can lead to tree mortality. Oaks larger than 46 cm (18 in) at breast height are typically killed by the goldspotted oak borer. Adult exit holes are D-shaped 4 mm (0.16 in) and found in the same regions as larval feeding. Exit hole densities can be extensive on trees. Adults feed very minimally on oak foliage by chewing tiny pieces from the edges.

Life History: In southern California, the goldspotted oak borer completes one generation a year. Adults emerge from oaks in mid-May and continue to fly until September. Adults most likely mate in the foliage before laying eggs in bark crevices or cracks on the main stem or larger diameter branches. Early instar larvae are most likely present in late spring to summer. Larvae mature and move from the sapwood surface to the outer bark where they pupate. Mature larvae are often found immediately under the bark in the fall to early spring in a hair-pin configuration. Pupation is estimated to take approximately two weeks during the early spring to summer.

Similar Insects: Other Agrilus spp., such as the twolined chestnut borer, *A. bilineatus*, and emerald ash borer, *A. planipennis*, are currently restricted to the eastern U.S. Bronze birch borer, *A. anxius*, is found in the western U.S., but is easily distinguishable from the goldspotted oak borer by coloration and host species.

Management Strategies: Goldspotted oak borer larvae have been recovered in firewood, so proper management of firewood is a necessity. Firewood can be 1) ground in to 7.6 cm (3 in) or smaller pieces; 2) have the bark removed; or 3) tarped and solarized to reduce beetle populations. Tarping firewood should begin early in May and continue until September. Completely cover firewood with thick, clear plastic sheeting and place in a sunny location. Systemic insecticide treatments (imidacloprid and emamectin benzoate) were effective at killing adults in lab feeding assays. Systemic treatments should be reapplied once every two years. Contact insecticides (carbaryl and bifenthrin) killed adults in lab feeding and walking assays. Contact insecticide applications should be reapplied every year. Deep watering every six weeks, mulching, and fertilizing can improve tree health, but no data currently supports this treatment for saving trees from goldspotted oak borer-caused mortality.

References

Fisher, W.S. 1928. A revision of the North American species of buprestid beetles belonging to the genus Agrilus. Smithsonian Institution, United States National Museum, Bulletin 145, 347 pp.

Coleman, T.W. and Seybold, S.J. 2008. New pest in California: The goldspotted oak borer, *Agrilus coxalis* Waterhouse. USDA Forest Service, Pacific Southwest Region, State and Private Forestry. Pest Alert R5-RP-022. October 18, 2008.

Coleman, T.W. and Seybold, S.J. 2008. Previously unrecorded damage to oak, Quercus spp., in southern California by the goldspotted oak borer, *Agrilus coxalis* Waterhouse (Coleoptera: Buprestidae). Pan-Pacific Entomologist. (In press)

Sirex Woodwasp (*Sirex noctilio*)

Hosts: Monterey, loblolly, slash, shortleaf, ponderosa, lodgepole, and jack pine.

Distribution in California: Not established in California; Sirex woodwasp has been the most common species of exotic woodwasp detected at United States ports-of-entry associated with solid wood packing materials. It is native to Europe, Asia, and northern Africa, where it is generally considered to be a secondary pest.

Sirex woodwasp

Photo: Kevin Dodds

Identification: Woodwasps (or horntails) are large, robust insects, usually 1.0 to 1.5 inches long. Adults have a spear-shaped plate (cornus) at the tail end; in addition, females have a long ovipositor under this plate. Larvae are creamy white, legless, and have distinctive dark spines at the tip of the abdomen. Key characteristics of the sirex woodwasp include: a dark metallic blue or black body; the abdomen of males is black with orange segments in the middle; legs reddish-yellow; feet (tarsi) black (males with black hind legs); and antennae entirely black.

Effects: Recent detections of sirex woodwasps outside of port areas in the United States have raised concerns because this insect has the potential to cause significant mortality of pines.

Life History: Sirex woodwasp is expected to complete one generation per year throughout most of the U.S. Adult emergence is likely to occur from July through September, with peak emergence during August. Females are attracted to stressed trees after an initial flight. They drill their ovipositors into the outer sapwood to inject a symbiotic fungus (*Amylostereum areolatum*), toxic mucus, and eggs. The fungus and mucus act together to kill the tree and create a suitable environment for larval development. Females lay from 25 to 450 eggs, depending upon size of the female. Unfertilized eggs develop into males, while fertilized eggs produce females. All larval instars feed on the fungus as they tunnel through the wood, but do not ingest the wood. The number of instars varies from 6 to 12, and the larval stage generally takes 10-11 months. Mature larvae pupate close to the bark surface. Adults emerge about 3 weeks later.

Similar Insects: Native woodwasps are similar in appearance and life cycles. Look for key identification features of Sirex woodwasp to distinguish it from native species.

Management Strategies: Sirex woodwasp has been successfully managed using biological control agents. The key agent is a parasitic nematode, *Deladenus siricidicola*, which infects sirex woodwasp larvae, and ultimately sterilizes adult females. These infected females emerge and lay infertile eggs that are filled with nematodes, which sustain and spread the nematode population. The nematodes effectively regulate the woodwasp population below damaging levels. As sirex woodwasp establishes in new areas, this nematode can be easily mass-reared in the laboratory and introduced by inoculating it into infested trees. In addition to the nematode, hymenopteran parasitoids have been introduced into sirex woodwasp populations in the Southern Hemisphere, and most of them are native to North America.

Modified from: Dennis A. Haugen, D.A and E.R. Hoebeke. 2005. Sirex woodwasp—*Sirex noctilio* F. (Hymenoptera: Siricidae), USDA Forest Service, Pest Alert, NA-PR-07-05.

Gypsy Moth (*Lymantria dispar*)

Hosts: The European gypsy moth prefers hardwoods but may feed on any of several hundred different species of trees and shrubs, including conifers. The Asian gypsy moth also has a wide host range but prefers conifers. Laboratory feeding studies have shown that gypsy moth can feed on a number of native California hardwoods, conifers, and brush species. Potential hardwood hosts include red and white alder, blue oak, California black oak, valley oak, Oregon white oak, coast live oak, and tanoak. Conifers include Douglas-fir, grand fir, red fir, white fir, Coulter pine, Gray pine, Jeffrey pine, Monterey pine, ponderosa pine, Torrey pine, coast redwood, giant sequoia, and western hemlock. Brush or chaparral hosts include flannel bush, manzanita, poison oak, salal, serviceberry, sugarbush, and toyon.

Distribution in California: Not established in California, but populations have established and eradicated; annual monitoring efforts have periodically detected individuals throughout the state. Well established in the eastern U. S. since 1869.

Gypsy moth larva

Photo: David Cappaert

Identification: Mature larvae are hairy and 38 to 64 mm (1 1/2 to 2 1/2 in) long; their heads have yellow markings, and their bodies are dusky or sooty-colored. On each of their backs is a double row of 5 pairs of blue dots, followed by a double row of 6 pairs of red dots. Pupae may be found attached by silken threads to the undersides of bark flaps, in crevices, under branches, on the ground, or almost anywhere that larvae rest. Pupae are naked and dark reddish-brown with some reddish hairs. Adult males are light brown moths with wingspans of 38 to 50 mm (1 ½ to 2 in). Females have buff-colored bodies and white forewings with patterns of light brown zigzags and rows of spots along the outer edges. Females of the European race have very heavy bodies and are flightless. Females of the Asian race have lighter bodies and are strong fliers. Masses of buff-colored eggs clothed in yellowish hairs are deposited in late summer on vertical surfaces, including tree trunks, branches, cars, trailers, ships, etc.

Effects: Larvae feed on host foliage, sometimes completely defoliating trees. First instar larvae chew small holes in leaves while the second and third stages feed from the outer leaf edges toward the centers. They are capable of defoliating entire stands of preferred host trees. There are currently no established populations in the western U.S., but travelers regularly introduce gypsy moths from other portions of the world. So far, defoliation in the western U.S. has been limited to a few recreational, urban, and suburban forest areas. Establishment of gypsy moth populations in the western U.S. could potentially be disastrous, especially if the Asian strain of the gypsy moth is involved. The Asian form is of special concern because it is a voracious feeder, shows a higher preference for conifer hosts, and is considerably more mobile than the European form.

Life History: Adults appear in late July and August. Females lay eggs in masses on trees or any vertical surface. Most introductions in the western U.S. have resulted from vehicles, trailers, or ships carrying egg masses into the region from elsewhere. Eggs overwinter and hatch in early spring about the time that leaves of hardwood hosts expand. Early instar larvae spin silk threads and may be blown considerable distances in the wind, distributing the population over wide areas. Older larvae also may migrate when original host trees are stripped of folaige. Pupation occurs in July and lasts 10 to 14 days.

Management Strategies: Aggressive monitoring programs are conducted in most western states using pheromone traps. When introductions are detected, eradication projects employing biological or chemical insecticides are instituted. So far, treatments have prevented establishment of permanent gypsy moth populations in the region.

References

Furniss, R.L., and Carolin, V.M. 1977. Western forest insects. USDA Forest Service. Miscellaneous Publication 1339. 654 p.

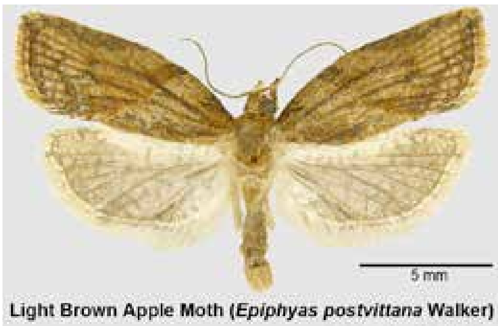
Light Brown Apple Moth (*Epiphyas postvittana)*

Hosts: Approximately 250 species of trees, shrubs and other plants

Distribution in California: The light brown apple moth (LBAM) is a native pest of Australia and is now widely distributed in New Zealand, the United Kingdom, Ireland, and New Caledonia. Although it was reported in Hawaii in the late 1800s, a recent LBAM detection in California is the first on the United States mainland. USDA confirmed the detection of LBAM in Alameda County, California on March 22, 2007. The California Department of Food and Agriculture (CDFA) aggressively surveyed the area to discover the extent to the infestation and identified the pest in coastal counties in central and southern California.

Adult light brown apple moth

Photo: Todd Gilligan



Identification: The adult insect is a moth about 10 mm (0.4 in) long when resting with the wings folded in a characteristic bell shape. Coloring is variable but they are generally yellowish-brown with darker brown markings on the forewings. Females often have a dark spot on the hind margin of the forewing. Newly hatched larvae (caterpillars) are very tiny, with a pale yellow-green body and a pale brown head.

Effects: LBAM is of particular concern because it can damage a wide range of crops and other plants including California's prized cypress as well as redwoods, oaks, and many other varieties commonly found in California's urban and suburban landscaping, public parks, and natural environment.

Life History: Females lay eggs between six and 10 days after moth emergence, depending on the temperature. Eggs are laid in masses on the upper surface of any smooth-leaved host plant. Eggs are flat, have a pebbled surface, and take from five to more than 30 days to hatch, depending on temperature. Early instar larvae wander actively over plant surfaces and may suspend themselves from a fine silken thread until they find a suitable feeding site. Young larvae prefer the underside of leaves and usually start to feed adjacent to a vein where they spin a protective cover of fine webbing. The pupa is at first green, but soon becomes brown after rapidly hardening, and then darkens during development. The pupa is typically found in a thin-walled silken cocoon between two leaves webbed together, and is usually 10-15 mm long; female pupae are larger than male pupae.

Similar Insects: There are many native tortricid moths that can be confused with LBAM. Adult moths must be identified by a qualified entomologist. Larval stages cannot be reliably identified using morphological characters. If you suspect the presence of LBAM, please notify your state department of agriculture or the State Plant Health Director's Office of USDA, APHIS, PPQ.

Management Strategies: USDA and CDFA have established quarantines in infested counties to control this pest before it has the chance to spread.

References

http://www.cdfa.ca.gov/phpps/pdep/lbam/lbam_main.html

http://www.aphis.usda.gov/plant_health/plant_pest_info/lba_moth/index.shtml

Asian Longhorned Beetle (*Anoplophora glabripennis)*

Hosts: Hardwoods such as maple, boxelder, birch, horse chestnut, poplar, willow, elm, hackberry, sycamore, mimosa and ash.

Distribution in California: The Asian longhorned beetle (ALB), native to China and Korea, was first discovered in the United States in 1996 on Long Island, New York. A second infestation was encountered in Chicago, Illinois in 1998. In the past decade, Asian longhorned beetles have been intercepted in the western region of the United States inside or near warehouses in Hawthorne, Los Angeles, South Gate, and Sacramento, California, and in Bellingham and Seattle, Washington.

Adult Asian longhorned beetle

Photo: Michael Bohne

Identification: The shiny black, bullet-shaped adult is about 2.5 to 38 cm (1 to 1.5 in) long with irregular sized and shaped white spots. Its black-and-white banded antennae are usually longer than its body. The elongated feet are black with a whitish-blue upper surface.

Effects: Asian longhorned beetle larvae bore deep into healthy deciduous hardwood trees eventually killing them. The impact on many of California's native hardwood species is currently unknown. Round exit holes, approximately 9.5 mm (0.4 in) in diameter, located on trunks and branches, egg laying sites, frass at the base of infested trees or in branch crotches and sap leaking from wounds on the tree may be the first clues to an infestation. An infested tree may have sudden die back of larger branches. Leaf symptoms show up when the larva damages tissues that transport water and nutrients to the canopy.

Life History: ALB has one generation per year. Adult beetles are usually present from July to October, but can be found later in the fall if temperatures are warm. Adults usually stay on the trees from which they emerged or they may disperse short distances to a new host to feed and reproduce. Each female is capable of laying up to 160 eggs. Eggs hatch in 10-15 days and larvae tunnel under the bark and into the wood where they eventually pupate. Adults emerge from pupation sites by boring a tunnel in the wood and creating a round exit hole in the tree.

Similar Insects: Native longhorned beetles such as the white spotted sawyer and the cottonwood borer very closely resemble the Asian longhorned beetle. Photos and identification materials are readily available to aid in identification.

Management Strategies: Asian longhorned beetle is not currently established in the western U.S., and the only acceptable approach to control is eradication. Early detection and reporting will help agencies to eradicate the pest and prevent its establishment.

References

http://www.wripmc.org/alerts/AsianLonghornBeetle.pdf

http://www.na.fs.fed.us/spfo/pubs/pest_al/alb/alb04.htm

Emerald Ash Borer (*Agrilus planipennis)*

Hosts: Potentially all North American ash species. As of 2004, Green ash, white ash and black ash, as well as several horticultural varieties.

Distribution in California: Not currently established in California. Emerald ash borer (EAB) is established in 21 states in the eastern U.S. EAB is native to northeastern China, Korea, Mongolia, and Japan. It is also native to the Russian Far East and Taiwan.

Mating emerald ash borers

Photo: David Cappaert

Identification: EAB adults are slender, elongate beetles, 7.5 to 15 mm (0.3 to 0.6 in)long and metallic, coppery-green in color. Mature larvae reach 26 to 32 mm (1 to 1.3 in) in length. Larvae are white, flat, slender, and have a pair of brown, pincer-like appendages on the last abdominal segment.

Effects: Emerald ash borer has killed ash trees across all size classes and health conditions in affected states. Larvae have developed in trees and branches ranging from 2.5 cm (1 inch) to 140 cm (55 inches)

in diameter. Emerald ash borer has killed vigorous trees in woodlots and urban trees under regular irrigation and fertilization regimes. However, stress likely contributes to the vulnerability and rapid decline of infested ash trees.

Life History: The emerald ash borer generally has a one-year life cycle in southern Michigan but could require two years to complete a generation in colder regions. Adult emergence begins in early June, peaks in late June and early July, and continues into late July. Beetles usually live for about 3 weeks and are present into mid-August. Adult beetles are active during the day, particularly when conditions are warm and sunny. Beetles feed on ash foliage, usually in small, irregularly- shaped patches along the margins of leaves.

Females can mate multiple times and egg laying begins a few days after the initial mating. Females can lay at least 60 to 90 eggs during their lifetime. Eggs are deposited individually in bark crevices on the trunk or branches. Eggs hatch in 7 to 10 days.

After hatching, first instar larvae chew through the bark and into the cambial region. Larvae feed on phloem and the outer sapwood for several weeks. The S-shaped feeding gallery winds back and forth, becoming progressively wider as the larva grows. Galleries are packed with fine, sawdust-like frass. Individual galleries often extend over an area that is 20 to 30 cm (0.8 to 1.2 in) in length, though the length of the affected area can range from 10 to 50 cm (3.9 to 19.6 in) or longer.

Feeding is completed in autumn and pre-pupal larvae overwinter in shallow chambers excavated in the outer sapwood or in the bark on thick-barked trees. Pupation begins in late April or May. Newly eclosed adults often remain in the pupal chamber for 1 to 2 weeks before emerging head-first through a D-shaped exit hole that is 3 to 4 mm (0.12 to 0.16 in) in diameter.

Similar Insects: Adult beetles are generally larger and a brighter green than the native North

American species of Agrilus.

Management Strategies: The North American ash resource is at risk from EAB. So far, all species of North American ash growing in the infested area have been successfully attacked. A 2002 Pest Risk Assessment concluded that EAB could potentially spread throughout the range of ash in North America and cause considerable economic and environmental damage. A vigorous research and management program along with harmonized quarantine actions are urgently needed to contain this new exotic tree pest.

References

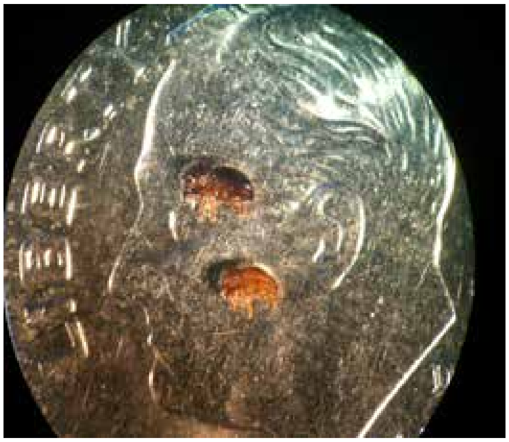
http://www.na.fs.fed.us/fhp/eab/pubs/mes/mes_eab47.pdf

http://www.emeraldashborer.info/index.cfm

http://www.na.fs.fed.us/spfo/pubs/pest_al/eab/eab04.htm

Polyphagous Shot Hole Borer *(Euwallacea* sp)

Hosts: In the western U.S., arroyo willow, avocado, big leaf maple, black bean, blue palo verde, box elder, brea, California Sycamore, camellia, castorbean, Chinese holly, coast live oak, coral tree, cork oak, engelmann oak, English oak, evergreen maple, Fremont cottonwood, Goodding's black willow, Japanese maple, mimosa, red willow, titoki, trident maple, tortuosa, valley oak, weeping willow, and white alder are attacked by the polyphagous shot hole borer. The ambrosia beetle prefers to attack willows, maples, California sycamore, and castorbean.



Polyphagous shot hole borer adult

Photo: Tom Coleman

Distribution in California: In 2003, the polyphagous shot hole borer was first collected near Los Angeles, CA, but the pest complex was not linked to tree injury and mortality until the spring of 2012. By 2013, the pest complex was detected in Los Angeles, Orange, San Bernardino, and San Diego Counties. The origin of the polyphagous shot hole borer is unknown, but it may have come from somewhere between northern Thailand and southern Japan. This beetle was also accidently introduced to Israel where it is a threat to hardwood trees in urban and agricultural settings. The polyphagous shot hole borer looks morphologically similar to the tea shot hole borer, *Euwallacea fornicatus*, which is native to southeastern Asia and has been accidentally introduced to several countries throughout the world.

Identification: Adults are oval in shape and brown to black in color. Adult females are approximately 2.62 (±0.02) (mean (±s.e.) mm long and 1.07 (±0.02) mm wide (Fig. 1) while adult males are smaller (approximately 1.80 (±0.02) mm long and 0.81 (±0.02) mm wide). Males are rarely observed because they are unable to fly, they typically do not leave the galleries, and very few are produced compared to females. Immature stages (eggs, larvae, and pupae) are white in color and restricted to the galleries in the xylem.

Effects: In southern California, the new pest complex has resulted in mortality of California box elder, California sycamore, castorbean, English oak, red willow, and white alder. California box elder and castorbean are frequently attacked and killed first. In urban areas of southern California, the pest complex threatens numerous ornamental species and an important fruit tree, avocado. In native forest stands, preliminary results show elevated levels of injury from the ambrosia beetle on California sycamore, castorbean, red willow, and white alder (ranging in size from 5−81 cm diameter at breast height (DBH)). Over 50% of these trees species were attacked over a period of a few years. Tree mortality has occurred at low levels in the native forest stand and likely takes greater than one year. Following extensive injury by the beetle, stem breakage has also occurred in smaller diameter trees (<13 cm DBH). Tree mortality is likely caused by the large numbers of beetles attacking a tree and their symbiotic fungi clogging the xylem. Likewise, the extent of tree injury and death in native forest stands is not yet known. In February 2013, the pest complex was first detected on the Angeles National Forest, but additional monitoring and research are needed to determine how susceptible or preferred other native hardwood species might be.

Mortality of native hardwoods from the pest complex can create potential hazards in and around high-use areas such as campgrounds and picnic areas. Dead trees should be felled to keep the areas safe and the wood should be managed properly to prevent the spread of the pest complex. Loss of hardwood species and canopy cover in riparian areas may cause habitat loss for several threatened and endangered species in southern California, including Bell's vireo, *Vireo bellii*, and the southwestern willow flycatcher, *Empidonax traillii extimus.*

Furthermore, excessive tree mortality may alter the structure and composition of the fuel load in areas already prone to wildfire.

Life History: The polyphagous shot hole borer likely completes two to four generations a year in the urban areas of southern Cailornia, but additional data are needed to verify the life cycle. Preliminary trapping of females and observational data suggest adults are active year round in urban areas and lower elevation (<610 m) forests. Females initiate attacks on hosts and excavate branching galleries in the wood. The female introduces their ambrosial fungi (*Fusarium euwallaceae*, *Graphium* sp., and *Sarocladium* sp.) to the galleries during construction, where it is the food source for both the adults and developing larvae. While in the galleries, female offspring mate with their flightless brothers, referred to as sibling mating. They then leave the galleries to look for locations to start new galleries, often in the same tree.

Similar insects: Native ambrosia beetles are associated with several hardwood species in southern California. These beetles typically attack stressed, dead, or dying trees, but can be found attacking the same tree as the polyphagous shot hole borer once tree health severely declines. Some of the ambrosia beetle genera commonly found attacking the same hardwood trees include *Monarthrum* spp. and *Xyleborus* spp..

Management strategies: Options are currently being developed for managing this new pest complex, but preventative management may only be necessary on a few of the most susceptible species. Preventative systemic or barrier insecticides may reduce beetle attack and ultimately prevent tree mortality, or systemic fungicides may hinder growth of fungi in the xylem. However, it is premature to recommend preventative management options. Removing heavily infested trees may reduce local populations of the beetle, but no data are available that support this management option. Furthermore, the removal of castorbean (>2.5 cm DBH), a heavily attacked species that is also an exotic, has been proposed at high-value sites to slow the establishment and population growth of beetle populations.

Green-infested material and wood from recently killed trees should not be removed from the infested area or taken out of the county. Movement of infested material can introduce the pest complex into additional areas of California. Chipping infested wood significantly reduces adult beetle emergence and developing larvae, but does eliminate all adult beetles. Chipped material should remain on site until adult emergence ceases. Tarping to heat and enclose infested material can reduce the emergence of beetles, but additional research is needed on these management options to determine their efficacy.

References:

Coleman, T.W., A. Eskalen, and R. Stouthamer. 2013. Pest Alert: New Pest Complex in California: The Polyphagous Shot Hole Borer, *Euwallacea* sp., and Fusarium Dieback, *Fusarium euwallaceae*. USDA Forest Service, Pacific Southwest Region, State and Private Forestry. R5-PR-032. November 4, 2013.

Eskalen, A., A. Gonzalez, D.H. Wang, M. Twizeyimana, J.S. Mayorquin, and S.C. Lynch. 2012. "First report of a *Fusarium* sp. and its vector tea shot hole borer (*Euwallacea fornicatus*) causing Fusarium dieback on avocado in California." *Plant Disease* 96: 1070-1070.

Eskalen, Akif, R. Stouthamer, S.C. Lynch, P.F. Rugman-Jones, M.Twizeyimana, A. Gonzalez, and T. Thibault. 2013. "Host Range of Fusarium Dieback and Its Ambrosia Beetle (Coleoptera: Scolytinae) Vector in Southern California." *Plant Disease* 97: 938-951.

Freeman, S., M. Sharon, M. Maymon, Z. Mendel, A. Protasov, T. Aoki, A. Eskalen, and K. O'Donnell. 2013. "*Fusarium euwallaceae* sp. nov-a symbiotic fungus of *Euwallacea* sp., an invasive ambrosia beetle in Israel and California." *Mycologia*. doi:10.3852/13-066

Animal Damage

This category would be very large if all levels of animal damage to all ages or sizes of trees were to be considered. However, the following discussion highlights the vertebrate pests which most commonly cause tree deformation.

Black Bear

Black bear damage

Photo: US Forest Service

Characteristics: Due to lack of available spring and early summer food sources, black bears strip bark from trunks and feed on the cambium. This is a learned feeding habit, handed down from sow to cub. Damage can range from minimal to severe, killing mature trees from this girdling. Commonly damaged species in California include coast redwood, Douglas-fir and Port-Orford-cedar. Trees within stands that respond with rapid growth one to two years following thinnings are likely bear targets.

Management Strategies: Since black bears are considered game mammals, any direct management actions will require consultation with the California Department of Fish and Game or the U.S. Fish and Wildlife Service. In extreme situations, killing or relocating bears may be considered.

Deer

Damage from deer browsing

Photo: Sue Hagle

Characteristics: Deer typically browse on palatable new growth, removing terminals and causing top-kill, stunting and tree malformation. Damage is usually confined to seedlings and saplings. Additionally, antler polishing in mid-summer strips the bark from stems and branches, sometimes causing mortality and malformation. Elk can cause similar injury. Hares and rabbits also can clip terminal branches on very small seedlings, though hare clipping will leave distinct oblique cuts on the branches, distinguishing the damage from deer feeding.

Management Strategies: Exclusion by fencing is effective for small blocks of trees. Exclusion tubes have proven effective for individual trees. Repellents have some utility but their effectiveness may be reduced by significant rainfall. Forest vegetation management that allows alternative food sources can also deter deer from feeding on seedlings.

Tree Squirrels

Bark removed by squirrel feeding on ponderosa pine.

Photo: Danny Cluck

Characteristics: Tree squirrels feed on thin-barked portions of stems with resultant girdling leading to top-kill and subsequent opportunity for sapwood decay. Damage is common on densely grown second growth redwood, Douglas-fir and pine. Similar injury may be caused by dusky-footed woodrats to saplings and poles on coastal species, and by porcupines to pole and small sawtimber pines.

Management Strategies: Tree spacing may be increased to prevent direct tree-to-tree migration of squirrels. For individual or high value trees, vertical squirrel movement may be prevented by removing lower branches and using metal banding (straight or conical) around the stem. Tree squirrels are game mammals. Encouraging recreational hunting in areas experiencing tree squirrel damage is an effective means on population management.

Pocket Gophers

Damage caused by pocket gophers

Photo: US Forest Service

Characteristics: Gophers feed on the roots and root collars of seedlings and saplings. Extensive root feeding or girdling at the root collar or stem causes mortality. Similar basal bark injury is produced by meadow voles, mountain beavers and porcupines, depending on location and seedling/sapling size.

Management Strategies: Mechanical traps may reduce pocket gopher populations, but the extensive burrow system requires diligence. Before considering chemical controls such as toxic baits or fumigants, consult with local county agricultural commissioners for registered products and follow all directions.

APPENDICES

Glossary

AERIAL SHOOT: Stem-like portion of dwarf mistletoe outside the host bark.

ALTERNATE HOST: Another host species required to complete development of an insect or pathogen.

BASAL CUP: The cup-like remnant of a dwarf mistletoe infection which remains visible long after the disintegration of an aerial shoot.

BLIGHT: A general term for a disease causing rapid death or dieback.

BROOD: All the individuals that hatch at one time from eggs laid by one set of parents.

BROWN ROT: A light to dark brown decay of wood that is friable and rectangularly checked in the advanced stage. Caused by fungi that attack mainly the cellulose and associated carbohydrates. The residue is chiefly lignin.

BUTT ROT: A rot characteristically confined to the butt or lower trunk of a tree.

CANKER: A definite, relatively localized, necrotic lesion primarily of the bark and cambium.

CONK: The bracket-like fruiting body of wood-destroying fungi.

CRAWLER: The active first-instar larva of a scale insect.

CULL FACTOR: A calculated percentage of the amount of merchantable wood lost from a tree as a result of decay or other defect.

DIEBACK: The progressive dying, from the tip downward, of twigs, branches, or tops.

ELYTRA: The chitinous wing covers of beetles.

ENDEMIC: A pest population that is at its normal, non-outbreak level within a region to which it is indigenous.

ENTRANCE COURT: The point of invasion of a disease organism into its host.

EPIDEMIC: Pertaining to pest populations that expand to a level that disrupts normal relationships in the forest ecosystem, often to the point of causing economic loss

FLAGS: Conspicuous dead branches with foliage remaining as a result of rapid killing by adverse abiotic conditions, insects, or disease agents.

FRASS: Solid excrement of insects; wood residue left by boring insects.

FUNGUS MAT: Dense, leathery mass of fungus mycelium often formed in decayed wood by certain wood-rotting fungi.

GALL: Enlarged, swollen growth of plant tissue.

GALLERY: A passage, burrow, or mine excavated by an insect in plant tissue for feeding, oviposition, or exit.

HEART ROT: Decay characteristically confined to the heartwood.

HONEYDEW: A sugary liquid excreted by aphids and scales.

HOST: The plant on or in which a pathogen or insect exists.

HOST-SPECIFIC: A term used to describe pest organisms that attack only certain species of hosts.

INCIPIENT ROT: The early stage of wood decay in which the wood is invaded and may show discoloration but is not otherwise visibly altered.

INOCULUM: The spores or tissues of a pathogen which infect a host.

LARVA (LARVAE): Immature form of an insect such as a caterpillar, grub, or maggot.

MAGGOT: A legless larva without a well-defined head.

MINED FOLIAGE: Leaves or needles in which the inner leaf tissues are eaten by insects.

MYCELIAL FANS: Similar in structure to mycelial felts but fan-shaped.

MYCELIAL FELT: A mass of fungus filaments that are arranged in a flat plane and resemble a thin felt-like paper or cloth.

MYCELIUM (MYCELIA): A mass of hyphae which forms the vegetative, filamentous body of a fungus.

NECROSIS: Death of plant cells usually resulting in darkening of the tissue.

NYMPH: An immature form of an insect resembling the adult except for incomplete wing development.

OBLIGATE PARASITE: A parasite incapable of existing independent of live host tissue.

PARASITE: An organism living on and nourished by another living organism.

PATHOGEN: An organism which causes a disease.

PERENNIAL CANKER: A canker resulting from disease organisms which do not kill woody tissue as rapidly as the host grows radially, leading to an annual killing and healing over of bark and cambial tissue.

PITCH TUBE: A tube-like accumulation of pitch around a bark beetle entrance hole on the bark of a tree.

POCKET ROT: A characteristic pattern of rot caused by certain fungi. The rot occurs in distinct, scattered pockets within the heartwood of a tree rather than in a distinct column.

PREDISPOSITION: The effect of one or more environmental or biotic factors which makes a plant vulnerable to attack by a pathogen or insect.

PROLEGS: Fleshy, false legs on the abdomen of caterpillars.

PUPA (PUPAE): Inactive stage of an insect; a transition stage from larva to adult.

RESINOSIS: A profuse flow or accumulation of resin from conifers injured or attacked by insects and disease.

RHIZOMORPHS: A specialized thread-or cord-like structure made up of parallel hyphae with a protective covering.

SAPROPHYTE: An organism using dead organic material as food.

SETA (SETAE): A bristle-like hair.

SKELETONIZED FOLIAGE: Leaves or needles in which the soft tissues between the veins have been eaten by insects, leaving only the veins.

SYMPTOM: A visually noticeable disturbances in the normal development and life processes of the host plant.

TUBERCLE: A small rounded projection from the surface of an insect.

VECTOR: A carrier of a disease-producing organism.

WETWOOD: A discolored, water-soaked condition of the heartwood of some trees presumably caused by bacterial fermentation.

WHITE ROT: Decay caused by fungi that attack all chief constituents of wood, leaving a whitish or light-colored residue.

WITCHES' BROOM: An abnormally profuse, dense mass of host branches and foliage. This is a common symptom induced by dwarf mistletoes as well as other parasitic and abiotic agents.

ZONE LINES: Narrow, dark brown lines in decayed wood.

Pest Detection and Reporting

Diagnosis: Observation is the key to the detection and identification of pest problems in forest stands and recreation sites. When losses occur, the problem must be accurately identified prior to the formulation of management alternatives. The first priority is to identify the species that is (are) affected. Then the stand conditions should be examined for any abnormalities or changes. This would include environmental conditions and cultural practices. Weather conditions of the recent past (2-3 years) should be evaluated. Cultural practices that have resulted in stump formation, slash buildup, or significant tree damage should also be considered. Correlation of symptomatic trees with site factors often provides useful information, as do observations on the distribution of symptomatic trees, such as grouped or scattered.

Following stand examination, inspection of individual trees can begin. Trees to be examined should include recently dead, dying, and symptomatic individuals. Older dead trees often are of little use. When examining trees one should be thorough and look at the entire tree and its surroundings. It is best to start at either the terminal end or the root system and systematically make observations throughout the tree. One should include exposing some roots to examine their condition. In addition to looking for insects and diseases, one should evaluate the progression of symptoms in the tree, terminal growth, foliage color, needle length and retention in conifers, branch dieback, pitch flow, and any other abnormalities. It is best to examine as many symptomatic trees as possible.

Once the necessary observations are completed, analysis of the accumulated information is necessary. One should not stop with the identification process when the first possible causal factor is determined. Much of the mortality in California is a result of the interaction of several factors, often including insects, disease organisms, and the environment. It is necessary to identify all elements of this complex in order to properly prescribe corrective actions.

Getting Assistance: Situations arise when the person in the field is unable to identify the problem. It is at this time when the Forest Pest Management Group can be of assistance. Specimens should be gathered and sent to the Northern California FPM office in the Shasta-Trinity Supervisor's Office. In situations where significant damage is occurring, a field evaluation may be requested. Personnel with non-federal agencies and private landowners should submit specimens and forms to the CDF headquarters in Sacramento. Accompanying the specimens should be a completed Forest Pest Detection Report (Form R5-3400-1).

Collecting Specimens: Insect and disease organisms should be collected and sent for identification, if available. However, the collected organisms should be related to the damage that is occurring. Insects observed in the process of causing damage should be collected. Care should be taken not to damage the specimens during collection. Fruiting bodies of suspected disease organisms should be collected, preferably from damaged tissues adjacent to green tissue.

When no organisms are available, collection of host tissue is required. Symptomatic material, by itself, may not be sufficient because it may simply be an expression of the problem rather than the problem itself. Material should be green or freshly killed; old dead tissue is not satisfactory. Base your decision on what material to collect on your field observations and experience.

Keep root specimens separate from other specimens to reduce contamination from the soil. Limit the size of specimens; large branches may be split to eliminate unaffected wood. Try to submit several representative specimens. Keep specimens out of sunlight and warm places and send in for identification as soon as possible.

Shipping Specimens: Specimens should be packed carefully in a mailing tube or sturdy carton. Sufficient padding should surround the specimens to prevent damage. Fresh specimens, or specimens from which fungal isolations will be necessary, should be put in perforated plastic bags, kept cool, and shipped as soon as possible. Schedule shipments so that they will arrive on weekdays. Keep free moisture out of the container to reduce the growth of unwanted organisms.

Immature insect specimens, such as caterpillars, should be shipped in vials containing a preservative such as ethyl or rubbing alcohol. A label, written in pencil, should be included in the vial. Moths and butterflies should be killed by exposing them to toxic vapors in a jar. Such vapors include ethyl acetate (nail polish remover), and sodium cyanide. After the moths are dead, fold their wings together and insert them in envelopes. Mail the envelopes in a carton with sufficient packing material so that the insects are not damaged. Other adult insects, such as beetles, should also be killed by exposure for two to three days to the previously mentioned toxic vapors. The insects should then be placed in a small container with tissue to prevent movement and breakage (no cotton wool please). This container can then be cushioned with packing material in a mailing carton and shipped to the proper office for identification.

Contributors

Forest Health Protection
USDA Forest Service, Regional Office
1323 Club Drive
Vallejo, CA 94592
Sheri Smith: 530.252.6667
Phil Cannon: 707.562.8913
Adam Ellis: 707.562.9168
email: ssmith@fs.fed.us
pcannon@fs.fed.us
.................adamlellis@fs.fed.us

Forest Health Protection
Lassen National Forest
2550 Riverside Drive
Susanville, CA 96130
Danny Cluck: 530.252.6431
Bill Woodruff: 530.252.6680
email: dcluck@fs.fed.us
wwoodruff@fs.fed.us

Forest Health Protection
Shasta-Trinity National Forest
3644 Avtech Parkway
Redding, CA 96002
Pete Angwin:
Cynthia Snyder: 530.226.2437
email: clsnyder@fs.fed.us

Forest Health Protection
Stanislaus National Forest
19777 Greenley Road
Sonora, CA 95370
Beverly Bulaon: 209.532.3672, 323
Martin MacKenzie: 209.532.3672, 242
email: bbulaon@fs.fed.us
mmackenzie@fs.fed.us

Forest Health Protection
San Bernardino National Forest
602 S. Tippecanoe Ave
San Bernardino, CA 92408
Tom Coleman:
Melody Lardner:
email: twcoleman@fs.fed.us

USDA Forest Service
State and Private Forestry
Forest Health Protection
1731 Research Park Drive
Davis, CA 95616
Jeff Moore: 530.759.1753
email: jwmoore02@fs.fed.us

Forest Pest Management
CA Dept. of Forestry & Fire Protection
118 S Fortuna Blvd
Fortuna, CA 95540
Chris Lee: 707.726.1254
email: christopher.lee@fire.ca.gov

Forest Pest Management
CA Dept. of Forestry & Fire Protection
P.O. Box 944246
Sacramento, CA 94244-2460
Tom Smith: 916.653.9476
email: tom.smith@fire.ca.gov

Forest Pest Management
CA Dept. of Forestry & Fire Protection
4050 Branch Rd
Paso Robles, CA 93446
Kim Corella: 805.550.8583
email: kim.camilli@fire.ca.gov

Forest Pest Management
CA Dept. of Forestry & Fire Protection
6105 Airport Road
Redding, CA 96002
Don Owen: 530.224.2494
email: don.owen@fire.ca.gov

FOREST PEST DETECTION REPORT

I. FIELD INFORMATION (See instructions on reverse)		
1. County:	**2. Forest (FS only):**	**3. District (FS only):**
4. Legal Description: **T. R.** **Section (s)** **5. Date:**	**6. Location:** **UTM:**	**7. Landownership:** National Forest ☐ Other Federal ☐ State ☐ Private ☐
8. Suspected Cause of Injury: 1. Insect ☐ 5. Chemical ☐ 2. Disease ☐ 6. Mechanical ☐ 3. Animal ☐ 7. Weed ☐ 4. Weather ☐ 8. Unknown ☐	**9. Size of Trees Affected:** 1. Seedling ☐ 4. Sawtimber ☐ 2. Sapling ☐ 5. Overmature ☐ 3. Pole ☐	**10. Part(s) of Tree Affected:** 1. Root ☐ 5. Twig ☐ 2. Branch ☐ 6. Foliage ☐ 3. Leader ☐ 7. Bud ☐ 4. Bole ☐ 8. Cone ☐
11. Species Affected:	**12. Number Affected:**	**13. Acres Affected:**
14. Injury Distribution: 1. Scattered ○ 2. Grouped ○	**15. Status of Injury:** 1. Decreasing ○ 2. Static ○ 3. Increasing ○	**16. Elevation:**
17. Plantation? 1. Yes ○ 2. No ○	**18. Stand Composition (species):**	**19. Stand Age and Site Class:** Age: Class:
20. Stand Density:	**21. Site Quality:**	
22. Pest Names (if known) and Remarks (symptoms and contributing factors):		

23. Sample Forwarded: 1. Yes ○ 2. No ○	**24. Action Requested:** 1. Information only ☐ 2. Lab Identification ☐ 3. Field Evaluation ☐	**25. Reporter's Name:**	**26. Reporter's Agency:**

27. Reporter's Address, email and Phone Number:

email: ____________________ phone: ____________

Address 1: ____________________

Address 2: ____________________

City: ____________ State: ____________ Zip: ________

II. Reply (Pest Management Use)

28. Response:

29. Report Number:	**30. Date:**	**31. Examiner's Signature:**

R5-3400-1 (Rev. 3/02)

Completing the Detection Report Form

Heading (Blocks 1-7): Enter all information requested. In Block 6, **LOCATION**, provide sufficient information for the injury center to be relocated. If possible, attach a location map to this form.
Injury Description (Blocks 8-15): Check as many boxes as are applicable, and fill in the requested information as completely as possible.
Stand Description (Blocks 16-21): This information will aid the examiner in determining how the stand conditions contributed to the pest situation. In Block 18 indicate the major tree species in the overstory and understory. In Block 19, indicate the stand age in years and/or the size class (seedling-sapling; pole; young sawtimber; mature sawtimber; overmature or decadent).
Pest Names (Block 22): Write a detailed description of the pest or pests, the injury symptoms, and any contributing factors.
Action Requested (Block 24): Mark "Field Evaluation" only if you consider the injury serious enough to warrant a professional site evaluation. Mark "Information Only" if you a reporting a condition that does not require further attention. All reports will be acknowledged and questions answered on the lower part of this form.
Reply (Section II): Make no entries in this block; for examining personnel only. A copy of this report will be returned to you with the information requested.
Handling Samples: Please submit injury samples with each detection report. If possible, send several specimens illustrating the stages of injury and decline. Keep samples cool and ship them immediately after collection. Send them in a sturdy container, and enclose a completed copy of the detection report.

Your participation in the Cooperative Forest Pest Detection Survey is greatly appreciated. Additional copies of this form are available from the Forest Service - Forest Health Protection, and from the California Department of Forestry and Fire Protection.

Forest Health and Related Websites

National Forest Health Website:
    http://www.fs.fed.us/foresthealth/
Forest Health Protection, R5:
    http://www.fs.usda.gov/main/r5/forest-grasslandhealth
Region 1 and 4, Field guide to insect and disease pests:
    http://www.fs.fed.us/r1-r4/spf/fhp/field_guide/index.htm
Region 1 and 4, Management guide to insects and disease pests:
    http://www.fs.fed.us/r1-r4/spf/fhp/mgt_guide/index.htm#top
Forest Pest Leaflets and other Forest Pest Information:
    http://www.na.fs.fed.us/spfo/pubs/fidlpage.htm
Vegetation Management Planning Guide-R2:
    http://www.fs.fed.us/r2/fhm/downloads/vmpguide.pdf
State and Private Forest Health for Nevada:
    http://www.forestry.nv.gov/main/health01.htm
Region 5 Hazard Tree Guidelines For Forest Service Facilities and Road
    http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5332560.pdf
Hazard Tree Information:
    http://www.na.fs.fed.us/spfo/pubs/uf/utrmm/
    http://na.fs.fed.us/fhp/hazard_tree/
Region 5 Danger Tree Awareness Toolbox:
    http://fsweb.r5.fs.fed.us/hazard/
International Society of Arboriculture Tree Care Info:
    http://www.treesaregood.com/
Hazard Tree Safety Initiative, Hazard tree, logger safety, fire and hazard trees, videos, etc:
    http://www.fs.fed.us/r1/projects/reference.shtml
FHP, R6, insect and disease websites and images
    http://www.fs.fed.us/r6/nr/fid/index.shtml
Photos of forest insects, diseases, and other useful images
    http://www.forestryimages.org/
National Pesticide Information Center, a joint project of Oregon State University & the US EPA
    http://npic.orst.edu/
Free pest leaflets from the University of California, Agriculture and Natural Resources. You can browse their regular catalog by clicking on the link.
    http://anrcatalog.ucdavis.edu/specials.ihtml
California Department of Pesticide Regulation home page
    http://www.cdpr.ca.gov/
California Department of Food and Agriculture home page
    http://www.cdfa.ca.gov/
Dr. Jim Worrall's online forest and shade tree pathology textbook
    http://www.forestpathology.org/
The official sudden oak death website with lots of useful links
    http://www.suddenoakdeath.org/
California Agriculture magazine on line
    http://danr.ucop.edu/calag/
Fire effects information system home page. Good source for native tree species information
    http://www.fs.fed.us/database/feis/index.html
UC Davis Integrated Pest Management – Lots of Home and Garden Information
    http://www.ipm.ucdavis.edu/index.html
California Department of Forestry, Pest Management
    http://www.fire.ca.gov/php/rsrc-mgt_pestmanagement.php
Region 5 POC Management Strategy
    www.fs.fed.us/r5/spf/publications/foresthealth/2006-10-31 FINAL POC Strategy.pdf

Pesticide Precautionary Statement

Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of the reach of children and animals--and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.