Forest Health Protection

Pacific Southwest Region

File	3420	Date:	January 30, 2004
Route:	2470		

Subject: Disease and Insect Conditions in Stand 103, Compartment 5, Downieville Ranger District, Tahoe National Forest (FHP Evaluation NE04-02)

To: District Ranger, Downieville Ranger District, Tahoe National Forest

At the request of Carla Kempen (Culturist, Downieville RD), Forest Health Protection (FHP) evaluated the insect and disease conditions in Stand 103 of Compartment 5 on the Downieville RD. The objective of this report is to provide input to Carla on disease and insect activity in Stand 103 and how this activity might effect proposed vegetative management projects for Stand 103. Bill Woodruff (FHP Plant Pathologist) and Carla examined Stand 103 together on October 2, 2003. Few tree diseases were detected and none was seriously impacting the stand. The most serious health issue present is the overstocking of the site with conifers, hardwoods and shrubs.

Existing Condition

Stand 103 is a mixed conifer stand heavily stocked with intermediate and suppressed trees. Average stand diameter is 14" dbh. Stocking is 2113 trees per acre (tpa). An average 588 tpa are 6" dbh or greater and 275 of these are 10" dbh or greater. The basal area is 605 ft^2/acre and the Stand Density Index is 942. Canopy cover averages 95 percent.

Ponderosa pine dominates the stocking with moderate numbers of incense-cedar and Douglas-fir and a small number of black oak. Large black oak are suppressed by conifers and are in poor condition. Tanoak and madrone are present in the understory in light to heavy amounts.

NORTHEASTERN CALIFORNIA SHARED SERVICE AREA
2550 RIVERSIDE DRIVE; SUSANVILLE, CA 96130 530-257-2151

Sheri Lee Smith
Supervisory Entomologist

Danny Cluck
Entomologist

William C. Woodruff
Plant Pathologist

There is a pocket of dead ponderosa pine, less than 10 trees, that was a result of a western pine beetle attack, probably occurring in the late 1990's. Some old ponderosa pine and Douglas-fir have *Phellinus pini* conks. One pine tree has a witches broom of unknown origin. Western gall rust can be occasionally found on ponderosa pine branches. Some of the madrone and tanoak trees are dead or have dead branches and/or lesions on their leaves. Tanoak and madrone leaves tested negative for *Phytophtora ramorum,* the pathogen which causes Sudden Oak Death (SOD)

Framework Direction

Stand 103 is within the Defense Zone of the Urban Wildland Intermix. The management direction for 90 percent of the stand area is to achieve an average live crown base height of 25 feet and average flame lengths of 4 feet or less if the stand was to burn under the 90^{th} percentile fire weather conditions. This is to be achieved by thinning from below to remove surface and ladder fuels. To enhance stand heterogeneity, 10 percent of the stand should remain untreated.

The proposed prescription is thin from below to reduce ladder fuels and to increase crown spacing where they overlap. This will reduce the risk of a crown fire and stimulate tree growth. Conifers will be removed from around large full-crowned oaks except when the oaks would be damaged by removing the conifer. No conifers larger than 29" dbh will be cut.

Insect and Disease Occurrences (See the Appendix for more information)

There is very little insect and disease activity in Stand 103. The biggest forest health concern is that the stand is overstocked with young conifers, hardwoods and shrubs. A small pocket (less than 10 trees) of large ponderosa pine snags are present. These pine appeared to have been killed in the late 1990's by western pine beetles. This mortality is an indicator that overstocking is stressing the trees here. Overstocking is probably a result of an altered fire regime over the past century whereby wildfire was artificially excluded from the ecosystem.

Two conifer diseases found in Stand 103 are red ring rot (*Phellinus pini*) and western gall rust (*Peridermium harknessii*). Fruiting bodies (conks) of *P. pini* were found on some of the old ponderosa pine and Douglas-fir trees. This disease is often associated with old conifers. *P. pini* is a heart rot which can structurally weaken its host if advanced decay is present.

Western gall rust was found incidentally on a few ponderosa pine branches. Western gall rust is a serious disease in nearby ponderosa pine plantations, demonstrating that the local environmental conditions favor this disease. Therefore, it is wise to favor non-host species such as Douglas-fir, white fir, sugar pine and incense-cedar in this area. Local stands where ponderosa pine is a small component seem to be minimally affected by western gall rust.

One large ponderosa pine had an old witches broom about 15 feet above the ground (Figure 1). Except for the broom, the tree appears healthy. No dwarf mistletoe (*Arceuthobium campylopodum*) plants were seen anywhere on this tree or on any nearby ponderosa pine, large or small. It is possible that this broom is elytroderma disease (caused by *Elytroderma deformans*). However no other elytroderma disease could be found in the area, either. It is also possible that this broom was caused by an isolated dwarf mistletoe infection which no longer is growing dwarf mistletoe plants. It was not possible to examine the broom close-up to see if there were any basal cups left by old dwarf mistletoe plants that were previously shed. A third possibility is that some unknown agent, such as animal feeding, either removed the dwarf mistletoe plants or caused the deformity. Whatever the cause, this broom seems to be an isolated occurrence which does not warrant special management. The broom does not appear to be harming the tree and it may be providing beneficial wildlife habitat.

Figure 1. Singular witches broom found in Stand 103

Diseased madrone trees are present in Stand 103. Madrone has a large number of foliar, stem and root pathogens (see Appendix). The pathogen most likely responsible for branch dieback on the madrones is *Fusicoccum aesculi* (sexual stage = *Botrosphaeria dothidea*). The pathogen most likely responsible for stem and branch cankers is *Nattrassia mangigerae*. Cankers usually develop from infections introduced through bark injuries. A branch or stem canker slowly girdles the stem and eventually kills the branch or tree. Suppressed (overtopped or overstocked) madrone trees are more likely to be affected by these diseases.

Tanoak is a major component in the understory in Stand 103. Some of the smaller tanoak are dead. Diseased leaves or dead branches were readily observed on tanoaks throughout the area. Overcrowding is probably responsible for most of the tree and branch mortality. However, tanoak is readily killed by Sudden Oak Death (SOD), caused by the recently discovered invasive pathogen, *Phytophthora ramorum*. Also, black oak and madrone are hosts for *P. ramorum*. The pathogen affects many other tree and shrub species, including rhododendron, California bay laurel, huckleberry, and California buckeye. The only way to confirm *P. ramorum* on a host is to analyze infected tissue in a lab. Samples of diseased tanoak and madrone leaves from suspicious plants in a nearby stand were sent to California's Plant Pest Diagnostic Center. The leaves tested negative for Sudden Oak Death. At this time, SOD has not been found in any Sierra Nevada.

Management Implications

Currently the insect and disease problems in Stand 103 are minimal. The overstocking will eventually result in bark beetle related mortality when the trees are stressed by prolonged periods of below normal precipitation. The small pocket of large dead ponderosa pine in the stand is a result of tree and shrub overstocking. Once the trees are dead secondary invaders like wood-boring insects and blue-stain or wood-rotting fungi colonize the wood and reduce the quality and quantity of recoverable wood.

A few of the old ponderosa pine and Douglas-fir trees are infected with *P. pini* which destroys heartwood and structurally weakens the trees. Whereas trees with advanced *P. pini* decay can be hazardous and lower in timber value than healthy trees, they none-the-less may have habitat value for cavity-nesting birds and associated wildlife. Currently western gall rust is minimally infecting a few ponderosa pine trees. Since this disease is a problem for nearby ponderosa pine plantations, it is wise to favor non-host species like Douglas-fir and incense-cedar in Stand 103.

The poor condition of the large black oak is a result of the combination of stresses experienced by them. Shading from the overstory and competition from surrounding vegetation slows growth and lessens vigor. This makes the oaks less resilient to the numerous diseases and insects that use black oaks as hosts. No specific pests were identified, but *Armillaria* spp. may be present. Releasing the black oaks from shade and competing vegetation in Stand 103 should help increase vigor and resilience to stress caused by disease and insects. Black oak can be killed by *P. ramorum* (sudden oak death). No signs of this disease were found. Since SOD has not been found killing trees in the Sierra Nevadas, there are no management constraints currently in effect. (See the appendix for damaging agents of California black oak, including *Armillaria* spp.)

Branch mortality, leaf lesions and tree mortality (mostly in the smaller trees) can be found in the madrone and tanoak in Stand 103. Shading and competition from surrounding vegetation is stressing these trees, large and small. Historically, natural wildfire probably kept the understory stocking of these trees low. Releasing individual madrone or tanoaks from shade and competing vegetation should increase vigor and resilience to stress. A number of damaging agents affect madrone and tanoak. The Appendix discusses the significant ones. As stated above, madrone and tanoak are hosts for *P. ramorum*. Again, there are no management constraints relating to this disease at this time.

<u>Summary</u>

Currently, diseases and insects are not seriously impacting the conifers in Stand 103. Hardwoods are overtopped and stressed by various pests. Overstocking in the under- and overstory is the biggest health-related problem. Without stocking reduction, future bark beetle mortality can be expected when the conifers are stressed by long periods of below normal precipitation.

The appendix of this report contains biological information for the diseases and insect discussed. More information on forest diseases can be found in USDA Forest Service, Agricultural Handbook 521: <u>Diseases of Pacific Coast Conifers</u>. A copy should be available at the North Yuba Ranger Station. If you need further assistance, please do not hesitate to call me at 252-6680.

WILLIAM C. WOODRUFF
Plant Pathologist

APPENDIX

Phellinus pini

Red ring rot, also called white pocket rot, is caused by a wood decay fungus, *Phellinus* (*Fomes*) *pini*, that attacks Douglas-firs, pines, true firs, hemlock, and rarely incense-cedar. It occurs throughout the coniferous forests of the world, and is the single most damaging heart rot organism in the West.

Red ring rot attacks young-growth as well as old-growth trees. It usually infects through branch stubs, and rarely through open wounds. Thus, this fungus may cause serious heart rot problems in managed stands of the future.

The perennial, woody fruiting bodies or conks that arise from the branch stubs or knots of living trees are the best indicators of decay. Sometimes only punky knots bearing the inner portion of the fruiting body remain on the stem. These punky knots may later be overgrown by new wood, becoming swollen knots that are the only symptom of decay. When conks or swollen knots are present, assume that advanced decay extends about 3-5 feet above and 5-7 feet below the indicator. If conks or swollen knots are visible along much of the stem, heart rot will be extensive.

Western Gall Rust

Western gall rust (Peridermium harknessii) causes branch galls and trunk cankers on nearly all species of hard pines. The rust fungus produces yellow to orange-colored spores (aeciospores) on the surface of the galls during cool, moist, spring weather the second or third year after infection. New crops of spores are produced yearly thereafter until the host tissue dies. Dispersal of spores by wind occurs usually in May and June. After spores land on susceptible tissues, especially after rainfall, some germinate and cause new infections. Most infections occur on current-year shoots. There is considerable yearly variation in the amount of infection in the West, where abundant infection in given stands occurs in relatively few years.

The fungus infects pines of all sizes and ages. Seedlings are the most susceptible and are often killed within a few years by girdling stem galls. In nurseries, galls may develop on seedlings as a result of infection by spores from surrounding infected stands and windbreak trees. Branch infections on mature trees usually are of slight importance; however, branch infections of highly susceptible trees may exceed 100 galls and consequently would reduce growth potential. Stem infections can result in growth loss and cull. Galls resulting in cankers may continue to grow slowly for more than 200 years eventually resulting in stem deformity. Cankers form weak points making stems and branches susceptible to wind breakage. Cankers also create avenues through which decay fungi can enter stems.

Armillaria Root Disease

Armillaria spp. is widely distributed in soils and usually lives as a saprophyte on dead wood or other organic matter. This fungus has a wide host range, including virtually all woody plants in California. It is frequently associated with hardwood roots, especially oaks. Healthy oaks are resistant to the fungus. This resistance disappears, however, when trees are weakened, stressed, cut, or killed, and *Armillaria* spp. may then rapidly colonize and decompose roots and sometimes entire root systems. Stresses that have been linked to increased damage from this root disease include insect defoliation, drought, excessive soil moisture, poor planting techniques, bark beetle attack, air pollution injury, and nutrient deficiencies.

The organic material used as a source of nutrition is called a food base. With a large food base to utilize, the fungus becomes more aggressive and moves to the roots of nearby trees by means of root contacts and rhizomorphs. Rhizomorphs are structures that resemble black shoestrings and grow like roots through upper soil layers. The predominant method of tree to tree spread in California is via root contact; rhizomorphs are more important and prevalent in other areas of the country.

Armillaria spp. is capable of directly penetrating through the intact root bark of living trees and once it reaches the cambium it usually grows rapidly, producing a flat, white, leathery, fan-shaped mycelial mat. Rhizomorphs are often associated with the mat. If the fungus reaches the root collar it girdles the stem and kills the tree. After *Armillaria* spp. successfully colonizes a root segment or root system, it continues to decay the wood and causes a white to yellowish, wet, stringy rot. This rot does not usually extend more than a few feet above the soil line.

Clusters of mushrooms may be found in the fall at the base of infected dead or dying trees and stumps. These mushrooms may also grow directly out of the soil near the food base. Spores produced by fruiting bodies are not an important source of new infections or long distance spread.

Western Dwarf Mistletoe

Dwarf mistletoes (Arceuthobium spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts. Western dwarf mistletoe (A. campylopodum) infects principally ponderosa, Jeffrey, and knobcone pines, and occasionally Coulter and lodgepole pines.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached, and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

Elytroderma Disease

The fungus Elytroderma deformans causes the most serious needle disease of ponderosa and Jeffrey pines in California. Occasional hosts include lodgepole, knobcone, Coulter, and pinyon pines. Unlike other needle diseases, Elytroderma infects twigs and branches systemically, allowing continued reinfection of a host's new needles even under adverse environmental conditions. Elytroderma impact is most severe in recreation forests, where the unsightly appearance of infected trees and occasional mortality can degrade the appearance and health of a stand.

Fungal fruiting bodies (hysterothecia) release spores from infected needles in late summer and early fall. Spores are windborne to susceptible hosts and, if environmental conditions are suitable, they germinate and infect the current year's needles. Initially, the fungus grows through the needle and into the twig without killing the needle. The following spring, infected needles die and turn a conspicuous red-brown. Infected branches take on a characteristic appearance, with current year's needles looking green and healthy while the one-year-old, infected needles are bright red-brown. Long, narrow, dull black fruiting bodies form on all surfaces of the dead needles and mature later in the summer, completing the infection cycle.Fungal mycelium within the twigs spreads into the growing tips and buds, deforming future branch growth. As a result, infected branches have a broomed appearance similar to that caused by dwarf mistletoes. However, Elytroderma brooms are distinguished by several characteristics: the red-brown color of one-year-old needles in spring and early summer; fruiting bodies scattered over the needle surface; resinous, brown necrotic lesions in the inner bark of twigs and branches infected for three years or more; and, a lack of mistletoe shoots or basal cups. Elytroderma disease kills one-year-old needles prematurely and deforms infected twigs and branches. Generally, pines are little affected if fewer than 40 percent of the twigs are infected. The disease seldom kills mature trees directly, but moderate-to-severe infection can predispose them to bark beetle attack. The disease is most severe on seedlings, saplings, and poles that are suppressed or have thin crowns. Disease outbreaks are uncommon, but once started, the disease can persist for many years, particularly in moist sites.

California Black Oak (*Quercus kelloggii*) -Damaging Agents
By Philip M. McDonald (forestworld.com)

Fire is black oak's worst enemy. Crown fires kill trees of all ages and ground fires are often fatal. Only a little radiative heat kills the cambium and only a small amount of flame along the trunk leaves long vertical wounds. Bark thickness on mature trees varies from 2 to 5 cm (1 to 2 in), but even the thickest bark provides little insulation to fire. Scars from burning can become a point of entry for fungi. On larger trees, repeated fires often enlarge old scars, sometimes toppling the tree. Fluctuations in weather also cause injury. Heavy, wet snow breaks branches and stems, particularly at forks, and sudden high temperatures following cool wet weather severely injure leaves.

California black oak is especially susceptible to fungi. Heart rot of the bole and large limbs of living trees, caused mainly by two pathogens, *Inonotus dryophilus* and *Laetiporus sulphureus,* is the principal damage. These rots enter the tree through broken branches or open wounds resultingfrom fire or logging. Both fungi often reduce the bole and large limbs of older, decadent trees to mere shells. The hedgehog fungus *(Hydnum erinaceus)* also is found in the heartwood of living trees and *Polyporus adustus* in the sapwood, though neither is prevalent.

By the time a natural black oak stand is 85 years old, the proportion of infected trees begins to increase rapidly. Almost 40 percent of trees 110 to 120 years old show incipient heart rot. Rotation age of stands grown for wood products could be influenced by this incidence-age relationship.

Another serious pathogen, *Armillaria mellea,* causes decay of the roots and butt of older decadent black oak. Sometimes it weakens the root system so much that the tree topples over on a perfectly calm, still day. This pathogen is indigenous in black oak, but younger vigorous trees do not seem to be affected by it.

A comparatively recent damaging agent to black oak in the San Bernardino Mountains of southern California is air pollution. Although the oak appears less susceptible to air pollution damage than associated conifers, radial growth has decreased in some trees. Where high ambient oxidant air pollution levels are chronic, damage to California black oak is expected to be significant.

One virulent pathogen that black oak escapes, and indeed is resistant to, is *Heterobasidion annosum*. For this reason, California black oak is being planted in numerous infection centers in southern California forests where conifers are dead or dying.

California black oak is prone to several leaf diseases including the oak leaf fungus *(Septoria quercicola),* oak anthracnose *(Gnomonia veneta),* powdery mildews *(Microsphaera* and *Sphaerotheca* spp.), a leaf blister fungus *(Taphrina caerulescens),* a leaf rust *(Cronartium* spp.*),* and true mistletoe *(Phoradendron villosum* subsp. *villosum).* Damage from each of these pests has not been determined but loss of growth increment probably is minor.

Animal damage to black oak is mostly from browsing. Foliage is eaten during all seasons, but especially in spring when new growth is tender and in winter when twigs are eaten. Deer eat acorns, seedlings, sprouts, and foliage. Even in midsummer, newly germinated seedlings with acorns attached often are consumed. Occasionally, browsing is fatal. In Mendocino County, CA, for example, a deer population of 1/2.4 ha (1/6 acres) almost eliminated oak over large areas of the Coast Range. Cattle also browse black oak, but in national forests, at least, their numbers are declining.

Many insects derive sustenance from black oak. The damage is usually secondary, reducing growth but seldom killing trees. Among sucking insects, the pit scales *(Asterolecanium minus* and *A. quercicola)* have the greatest potential for damage. The most destructive insect, however, is probably the carpenterworm *(Prionoxystus robiniae),* whose larvae mine the wood of trunk and limbs and cause injuries that appear later as defects in lumber.

Other insects are capable of heavy damage, especially when infestations become epidemic. The Pacific oak twig girdler *(Agrilus angelicus)* is the most damaging insect to oak in southern California during drought years. In northern California, the California oakworm *(Phryganidia californica)* is noted for defoliating trees. So is the fruit-tree leafroller *(Archips argyrospila)* which, in 1968, caused heavy damage throughout a wide area in the Sacramento River drainage.

Tanoak (*Lithocarpus densiflorus*) - Damaging Agents
By John C. Tappeiner, II, Philip M. McDonald, Douglass F. Roy (forestworld.com)
Fire is the principal enemy of individual tanoak trees. Ground fires, as well as crown fires, are sometimes fatal. More often, however, fires leave long vertical wounds reaching from 1.2 to 3.0 in (4 to 10 ft) up the trunks. Although the bark of mature trees is at least 3 to 8 cm (I to 3 in), and occasionally 10 or 13 cm (4 or 5 in) thick, some trees are burned badly.

Fire injuries to small trees often heal over, but fungi usually enter the wounds on older trees. The exposed wood on these larger trees rots and the wounds do not heal. If decayed wood catches fire it burns readily and the original wound is enlarged. Sometimes one-third to one-half the diameter of the tree is destroyed as a result of repeated fires and decay.

Until injured by fire, tanoak is relatively free from insect attacks and fungal diseases and is windfirm. Injury to the trunk, however, allows fungi to enter. Wind and heavy snows eventually fell many trees originally injured by fire and subsequently weakened by decay.

Fire and fungi cause tanoak to be fairly defective. One study based upon cubic volume in 90 trees showed that the amounts of saw log cull were 39 percent in cull trees, 8 percent in noncull trees, and 13 percent in all trees.

Fungi found in living trees are the beefsteak fungus *(Fistulina hepatica),* which causes a brown cubical rot; the weeping conk *(Inonotus dryadeus),* a white root rot; and a necrophyte *(Schizophyllum commune),* which causes a sap rot on injured areas of standing trees. Tanoak is susceptible to the shoestring root disease *(Armillaria mellea).* The fungus *Ceuthocarpum conflictum* causes a commonly seen leafspot on tanoak.

Several insects have been found feeding on tanoak but, generally, the damage is not economically significant. Two of these are armored scales identified as the greedy scale *(Hemiberlesia rapax)* and the oak scale *(Quernaspis quercus).* The greedy scale chiefly infests the bark but also feeds on leaves. The oak scale feeds on the undersides of leaves. Another insect, the crown whitefly *(Aleuroplatus coronatus),* resembles soft unarmored scales and feeds on the undersides of leaves, sometimes causing the leaves to fall prematurely. Ehrhorn's oak scale *(Mycetococcus ehrhorni) is* found on stems and the white sage mealybug *(Pseudococcus crawi)* on stems and leaves.

In 1957, the California oakworm *(Phryganidia californica)* completely destroyed that year's foliage of tanoaks growing on Hennessey Ridge, near Salyer, Trinity County, CA. This damage was localized and was not observed at other places nearby. Usually, the California oakworm causes little damage but irregularly becomes epidemic over large areas.

Other insects work under the bark. Adults of the Pacific oak twig girdler, *Agrilus angelicus,* feed on foliage, but its larvae mine spiral galleries that girdle twigs, small limbs and trunks, or sprouts. Adults of a false powderpost beetle *(Mela1gus confertus)* prune twigs by boring at the fork of small branches.

Decline of tanoak sprout vigor was observed in mixed conifer-hardwood forests in the central Sierra Nevada . Affected clumps were wider and denser, but only one-fifth as tall as unaffected clumps. Reason for the decline is not known.

Diseases of Pacific Madrone

Marianne Elliott - College of Forest Resources, University of Washington, Seattle, WA

Abstract

Madrone is the host for a variety of pathogenic fungi. Many of these are foliar pathogens and are not a serious threat to the health of the tree. In recent years, several canker fungi have become a problem, causing damage and even death of large madrone trees in urban areas. The three pathogens most likely to cause tree death are *Phytophthora cactorum, Nattrassia mangiferae*, and *Fusicoccum aesculi*.

Introduction

Diseases of madrone can be classified into root rots, stem and branch cankers, branch dieback, wood decay, and foliage disease (Table 1). They can also be organized by class, and many of the fungi in a given class affect the same parts of the tree. An understanding of the life cycles of fungi can be useful in learning how to control diseases.

Root Rots

Seedlings of madrone are susceptible to damping-off and root rot fungi. As madrone trees age, they develop a large root burl with a spreading root system. This allows the tree to resprout when damaged by fire or disease. The most common root disease in mature madrone trees is *Phytophthora* root rot. *P. cactorum* is the species which attacks madrone. It can infect the roots as well as the main stem of the tree. Cankers are usually at the base of the tree, although they can also occur further up on the stem (Stuntz 1943). The cankers on the trunk sometimes appear water-soaked. The infected bark is discolored brown, in contrast to the healthy inner bark, which is cream-colored. The sapwood can also be discolored to a depth of one to two millimeters. The symptoms that can be seen in the crown are loss of foliage in the upper crown and abnormally small leaves with curled margins. If the disease kills the tree quickly, the leaves remain attached and wilted. Trees planted in poorly drained soil are the most susceptible (Sinclair, 1987).

Phytophthora is in the class Oomycetes, which also includes the damping-off fungi. The Oomycetes are characterized by having an aseptate mycelium, chlamydospores, which are resting structures that allow the fungus to survive harsh conditions, sexual oospores, and swimming zoospores. The spores require free water to germinate, exist in the soil and on diseased plant debris, and can be spread through running water and rain splash. The most likely places for infection are wounds and the succulent portions of shoots and feeder roots. The Oomycetes have no fruiting bodies, and their reproductive structures are microscopic, so identification of the disease is largely based on symptoms and examination of the fungus in culture.

Annosus root rot is caused by the Basidiomycete fungus *Heterobasidion annosum*. This fungus is known as a problem on coniferous trees and has been found to attack and kill madrone in Amador county, California (McDonald 1991). If the soil contains a large amount of conifer roots colonized by *H. annosum*, they can be used as a food source by the fungus to overcome the defenses of the hardwood trees in the area (Sinclair 1987). *H. annosum* attacks woody roots and also causes a butt rot. The decay is a white pocket rot or a white stringy rot, and varies with the type of host. The fruiting body is a flat and buff colored conk, and is difficult to find. The conks can be found on the underside of roots or inside a hollow stump, and rarely on exposed surfaces. The spores of *H. annosum* are spread by the wind to infect wounds or freshly cut stumps.

Stem and Branch Cankers

Cankers usually develop after an injury to the bark of the tree (Hunt, 1992). The wound becomes infected with a fungus that grows in the cambium and resists the host response. If the tree is vigorous enough, it can callus over the tissue killed by the canker fungus. Where the fungus kills the cambium, the area appears sunken. Canker fungi can kill the branch or the whole tree by girdling, and provide an entry court for decay fungi. The branch or trunk becomes weak at the location of the canker, and may snap off in the wind.

Arbutus canker is caused by the fungus *Nattrassia mangiferae* (Deuteromycetes). This fungus has a wide host range, occurring on many tropical plants, orchard trees (English 1974), and even humans (Moore 1988), where it can cause infections of the nails. The cankers first appear as an area of bark discoloration. The bark peels off, revealing dark masses of fungal spores and longitudinally cracked wood. The asexual spores are present all year in the dead wood of the canker, and are carried by the wind to infect new hosts (Hunt 1992). A callus ridge forms around the margin of the canker. In some cases this can be very raised and knobby in appearance. More rapidly spreading cankers have a smooth margin and no callus. Cankers are most commonly found on the parts of trees that are exposed to strong sun, or that have been injured by pruning or other mechanical causes (Davison, 1972). Cankers can be prevented by minimizing wounding, and preventing sudden exposure of trunks to the sun (Hunt, 1992, Sunset, 1987). If the cankered branch is to be removed, it should be cut well beyond the canker margin, as the fungus spreads some distance into the wood.

Nattrassia mangiferae is in the class Deuteromycetes. Fungi in this group are called the "fungi imperfecti" because they reproduce by means of conidia and no sexual stage has been found for most species. They cause many foliage diseases and canker diseases, and are most often members of the Ascomycetes, and more rarely the Basidiomycetes. Their life cycle follows the asexual part of the Ascomycete life cycle, with the mycelium producing large amounts of conidia while conditions are favorable. Some of these fungi form sclerotia or chlamydospores in order to survive adverse weather. Other pathogens of madrone in this group are *Fusicoccum aesculi* (asexual stage) and some of the foliar pathogens.

Branch Dieback

Branch dieback usually works in conjunction with canker fungi. It is caused by the fungus *Fusicoccum aesculi* (Deuteromycetes). Its sexual stage, *Botryosphaeria dothidea* (Ascomycetes), is a pest on orchard trees, and trees of tropical plantations (Gilbert 1996). The disease is also called "madrone canker", and begins at the branch tips, moving inward. The bark is a dark red , turning black and looking burned after the branch is dead. The infection girdles and kills the branch. Tiny, pinhead sized fruiting bodies appear in the succulent parts of the branch tip and on the leaves. The spores are spread by rain and wind, and possibly insects (McDonald 1991).

This fungus does not attack vigorous trees. Its hosts are trees that are weakened by other canker fungi or are under water stress. It has been shown that fungal growth stops when the host is receiving sufficient water (Boyer 1995). When the host is under water stress, photosynthesis decreases and fungal growth increases.

This disease can be prevented by keeping the tree watered during the growing season and during dry periods. Branches that have died back should be removed and destroyed.

Sometimes a rapidly growing *Nattrassia* canker can be mistaken for a *Fusicoccum* infection, as the two look similar with their cracked, blackened bark. The two fungi have been found in the same canker on almond (English, 1974).

Wood Decay

Many wood decay fungi are found on madrone, and utilize the dead wood. There are a few species that decay the heartwood of living trees. In natural forests, these trees are used by cavity-nesting birds (McDonald 1991). Wood decay fungi are all Basidiomycete fungi that form conks, or perennial fruiting bodies. The basidiospores land in an area where the wood has been killed, usually by a canker fungus. The wood appears cracked or crumbly, and is structurally weak. As mentioned previously, damage by these fungi can cause the tree to weaken and be a potential hazard in urban areas.

The class Basidiomycetes includes all the wood decaying fungi, the root and butt rot *Heterobasidion annosum*, and the foliar pathogen *Exobasidium vaccinii*. Rusts are Basidiomycetes with a complicated life cycle involving several hosts, and only one has been reported on madrone (Hepting 1971). Its alternate host is a European spruce species.

The life cycle begins when a basidiospore lands on a suitable substrate, germinates, and forms a mycelium. When it contacts another mycelium of a compatible mating type, they exchange nuclei and form a dikaryotic mycelium. Then, the fruiting body forms and meiosis occurs. In the wood decaying fungi, the fruiting body is most often a conk, and in a few cases a mushroom. The resulting basidiospores are borne on the outside of a special structure, the basidium. These spores are mostly dispersed by the wind.

Foliage Diseases

The leaf is a prime target for pathogenic fungi, because it has a high concentration of simple sugars derived from photosynthesis. Madrone has a large number of these fungi associated with it (Table 1), since the leaves are retained for a longer period of time than on deciduous hardwoods. Leaves generally remain on the plant for two years, then abcise around the time that new leaves are forming in the spring. Foliar pathogens are more successful at colonizing senescent leaves than new leaves. In madrone, new foliage is rarely infected until fall (Hunt 1992). The spores are produced on infected leaves from the previous year, or in lesions on the branches. They are spread by wind and rain. Leaf pathogens are mostly in the Ascomycetes or Deuteromycetes, with a few exceptions. Foliage diseases intensify during periods of warm, wet weather. In some years, there is heavy damage to the foliage and most is lost. The infected foliage is replaced by new leaves in the summer, and the trees look healthier than others around them which may be suffering from summer drought.

Coccomyces quadratus and *Rhytisma arbuti* (Ascomycetes) are two pathogens that only attack madrone (Hunt 1992). They both reproduce by means of sexual spores that are released when wet. The fruiting body of *R. arbuti* is a speckled tar spot. Early in the season, the fungus produces pycnidia with one-celled asexual spores. The infected tissues later become sclerotia, a form that is resistant to adverse weather and allows the fungus to survive until conditions are more favorable. It also forms apothecia with sexual spores that are long and narrow. This fungus is one of the most damaging as it can overwinter on attached foliage. *C. quadratus* forms a large tar spot.

Most of the foliar pathogens and the sexual stage of *Fusicoccum aesculi* belong to the class Ascomycetes. They all have a similar life cycle. The sexual spores, called ascospores, are airborne and are released from the fruiting body on the leaf. This usually happens during wet weather, particularly in the spring. The ascospores land on another leaf of a suitable host and germinate. They colonize the leaf and form another fruiting body and asexual spores, called conidia. In the summer, the conidia are dispersed by wind and rainsplash, infecting more leaves. The mycelium will continue to produce conidia as long as the conditions are favorable, and large quantities can be produced in a single season. The same mycelium then produces asci, and genetic material is exchanged between mycelia of compatible mating types. The ascospores overwinter on dead leaves, to begin the cycle again in the spring.

Didymosporium arbuticola and *Diplodia maculata* (Deuteromycetes) are two asexually reproducing fungi found only on madrone. Their fruiting bodies are small leaf spots. *D. arbuticola* forms brown spots with purple to reddish margins, 3-6 mm in diameter (Hepting 1971).

Exobasidium vaccinii (Basidiomycetes), or blister blight, forms pinkish blisterlike galls on the leaves, making them distorted and twisted. It also attacks the fruit, making it turn red and swell to several times its natural size. The basidiospores are formed on the underside of the leaf blisters and on the surface of the infected fruits in a thin layer of fungal tissue. They are ejected during wet weather.

Foliage diseases are rarely a threat to the survival of the tree, even though it may look that way. The amount of inoculum can be reduced by removing dead leaves and pruning infected twigs. Leaves that have fallen are another source of inoculum and should be raked in the late summer or early fall. When watering madrone or nearby plants, care should be taken not to splash the foliage as this spreads the spores.

Isolation and Identification

Isolating the fungi which cause diseases of madrone is a fairly simple procedure. Pieces of infected tissue are removed from the plant and washed in a dilute solution of Clorox and water, then rinsed in water. The tissue is put in a petri dish containing a suitable nutrient medium, such as 2% malt agar, and incubated at room temperature. After about a week, colonies form, and can be observed in the microscope. It can take longer for fruiting structures to form in some fungi. The fungi of interest are transferred to another petri dish to obtain a pure culture. Isolating *Phytophthora* is more difficult, and some techniques can be found in the book by Ribiero (1978).

Not all the fungi are as easy to identify as *Nattrassia*, which has a distinctive hyphal structure (Sutton and Dyko 1989). Some useful books for identifying the Deuteromycetes are the ones by Barnett (1972) and Carmichael (1980). There is a good description of *Phytophthora cactorum* isolated from madrone in the article by Stuntz (1943). Some fungi are more easily identified by their symptoms on the tree than in culture. Inoculating a healthy tree with a fungus that has been isolated from a diseased tree and observing the symptoms is how this is usually done.

References

1. Barnett, H.L., and B.B. Hunter. 1972. Illustrated genera of Imperfect Fungi. Burgess Publishing Co.
2. Boyer. J.S. 1995. Biochemical and biophysical aspects of water deficits and the predisposition to disease. Ann. Rev. Phytopath. 33:251-74.
3. Carmichael, J.W., Kendrick, W.B., Conners, I.L., and L. Sigler. 1980. Genera of Hyphomycetes. University of Alberta Press.
4. Davison, A.D. 1972. Factors affecting development of Madrone canker. Plant Dis. Rep. 56:50-52.
5. English, H., Davis, J.R., and J.E. DeVay 1974. Relationship of Botryosphaeria dothidea and Hendersonula toruloidea to a canker disease of almond. Phytopathology 65:114-122.

6. Gilbert, G.S., and DeSteven, D. 1996. A canker disease of seedlings and saplings of Tetragastris panamensis (Burseraceae) in a lowland tropical forest. Plant Dis. 80:684-687.
7. Hepting, G.H. 1971. “Diseases of Forest and Shade Trees of the United States”. USDA Handbook #386:76-78.
8. Hunt, R.S, and A. Funk. 1992. Common Pests of Arbutus. Canadian Forestry Service, FPL 63, Victoria, B.C.
9. McDonald, P.M., and J.C. Tappeiner, II. 1991. Arbutus Menziesii Pursh Pacific Madrone. USDA Agricultural Handbook #567:124-132.
10. Moore, M.K. 1988. Morphological and physiological studies of isolates of *Hendersonula toruloidea* Natrass cultured from human skin and nail samples. Journal of Medical and Veterinary Mycology 26: 25-39.
11. Ribeiro, O.K. 1978. A Source Book of the Genus Phytophthora. J. Cramer In der A.R. Gantner Verlag Kommandgessellschaft FL-9490 Vaduz
12. Sinclair, W.A. 1987. Diseases of Trees and Shrubs. Cornell Univ. Press.
13. Sutton, B.C., and Dyko, B.J. 1989. Revision of Hendersonula. Mycological Research 93:466-488 Stuntz, D.E., and Seliskar, C.E. 1943. A stem canker of dogwood and madrona. Mycologia 35:207-221.
14. Sunset magazine 1987. “What's killing the Northwest's madronas?” December issue, p. 198.

Table 1. Fungal pathogens of madrone.

	Common name	**Where found**	**Class**	**Reference**
Root Rots				
Pythium spp.	Damping-off of seedlings	General	Oomycetes	McDonald 1991
Phytophthora cactorum	Phytophthora root rot	Seattle, WA to northern California	Oomycetes	Hunt 1992, McDonald 1991, Stuntz 1943
Heterobasidion annosum	Annosus root rot	Amador county, California	Basidiomycetes	McDonald 1991, Sinclair 1987
Stem and branch cankers				
Phytophthora cactorum	Phytophthora canker	Seattle, WA	Oomycetes	Hepting 1971,
Natrassia mangiferae	Arbutus canker	British Columbia to Southern Oregon	Deuteromycetes	Hunt 1992, McDonald 1991
Branch dieback				
Fusicoccum aesculi	Madrone canker	British Columbia to Northern California	Deuteromycetes	McDonald 1991

Table 1. Fungal pathogens of madrone. (continued)

	Common name	**Where found**	**Class**	**Reference**
Wood decay				
Phellinus igniarius	White rot	British Columbia to Northern California	Basidiomycetes	Hepting 1971, McDonald 1991
Fomitopsis cajanderi	Brown top rot	British Columbia to Northern California	Basidiomycetes	Hepting 1971, McDonald 1991
Poria subacida	Yellow root rot	British Columbia to Northern California	Basidiomycetes	Hepting 1971, McDonald 1991
Foliage diseases				
Ascochyta hanseni	Leaf spot	California, Texas	Deuteromycetes	Hepting 1971
Coccomyces quadratus	Tar spot	British Columbia	Ascomycetes	Hunt 1992
Cryptostictis arbuti	Leaf spot	Oregon, California	Deuteromycetes	Hepting 1971
Didymosporium arbuticola	Leaf spot	General	Deuteromycetes	Hepting 1971, Hunt 1992
Diplodia maculata	Leaf spot	British Columbia	Deuteromycetes	Hepting 1971, Hunt 1992
Disaeta arbuti			Deuteromycetes	Hepting 1971
Elsinoe mattirolianum	Spot anthracnose	Southern California	Ascomycetes	Hepting 1971
Exobasidium vaccinii	Blister blight	General	Basidiomycetes	Hepting 1971, Hunt 1992
Mycosphaerella arbuticola	Leaf spot	General	Ascomycetes	Hepting 1971
Phyllosticta fimibriata	Leaf spot	California	Deuteromycetes	Hepting 1971
Pucciniastrum sparsum	Rust		Basidiomycetes	Hepting 1971
Rhytisma arbuti	Speckled tar spot	General	Ascomycetes	Hepting 1971, Hunt 1992

Sudden Oak Death

Sudden Oak Death is a forest disease caused by the fungus-like pathogen *Phytophthora ramorum.* This pathogen has caused widespread dieback of tanoak and several oak species in the central and northern coastal counties of California. It has also been found on numerous other species, including Douglas fir, rhododendron, California bay laurel, and camellia. While some of these species - coast live oak, black oak, Shreve oak and tanoak - sustain lethal trunk infections, other plants get more benign foliar and twig infections. Many of these species with foliar infections play a key role in spread of *P. ramorum* by acting as a reservoir of innoculum, which may then be spread aerially via wind blown rain. Sporangia and chlamydospores, the most likely propagules of dispersion, are commonly generated on foliage, whereas they have not as yet been found on infested oak bark. The two plants determined to be the greatest sinks for innoculum are California bay laurel/Oregon myrtle and *Rhododendron* spp. Mortality is most common where oaks and these foliar hosts are found growing together.

At present, there are 38 species known to be susceptible to the *Phytophthora ramorum*. 22 of these have been recognized as regulated hosts by the United States Department of Agriculture, Animal and Plant Health Inspection Service - Plant Protection and Quarantine (USDA-APHIS-PPQ), and by the California Department of Food and Agriculture (CDFA). An additional 16 plant species are listed as associated with *Phytophthora ramorum*. Associated plants are those found in nature from which *P. ramorum* has been cultured or detected using PCR (Polymerase Chain Reaction). For each of these, Traditional Koch's postulates have not yet been completed or documented and reviewed. Though not regulated and not requiring certification under *P. ramorum* regulations, these plants will be inspected in nurseries and Christmas tree plantations and, if symptoms are observed, held from sale pending testing.

Depending on the plant species, infection may occur on the trunk, branches, and/or leaves. Infections on woody portions of the tree are referred to as cankers. Cankers on the trunk of oak trees are the most damaging. Tree death appears to occur when cankers expand in the trunk (girdling) and disrupt physiological function. Diseased oaks are often attacked by other pest organisms -- fungi that decay sapwood (*Hypoxylon thourasianum*) and bark beetles. In the shrub species the symptoms can range from leaf spot to twig girdling, and do not necessarily result in death of the plant.

Phytophthora ramorum appears to thrive in cooler, wetter climates. In California, it is found only in the coastal counties. The means of dispersal include wind blown rain splash and infested plant material. Plants infected with *P. ramorum* had been observed in 12 counties along the west coast of California. Those counties are, from north to south: Humboldt, Mendocino, Sonoma, Napa, Solano, Marin, Contra Costa, Alameda, San Mateo, Santa Clara, Santa Cruz, and Monterey.

More information on Sudden Oak Death can be found on the California Oak Mortality Taskforce webpage at:

http://nature.berkeley.edu/comtf/html/science_and_mgmt__materials.html

<u>Western Pine Beetle</u>
The western pine beetle (WPB), *Dendroctonus brevicomis*, breeds in the main bole of living ponderosa and Coulter pine larger than about 4 inches dbh. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire.

Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latitude and elevation, there can be from one to four generations per year. The generations are difficult to distinguish because the prolonged period of initial attack and re-emergence of parent females to establish additional broods causes considerable overlapping of the generations. Initial attacks are made near mid-bole and subsequent attacks fill in above and below. Phermones released during a successful attack attract other western pine beetles. Attacking beetles may spill over onto nearby apparently healthy trees and overwhelm them by sheer numbers. Pitch tubes and red boring dust are indications of successful attacks.

Adults bore a sinuous gallery pattern in the cambium and the female lays eggs in niches along the sides. The larvae feet in the inner bark for a short distance and then bore into the outer bark to complete development. It is common to see WPB infested ponderosa pine trees with large areas of inner bark layers exposed on the bole resulting from woodpeckers flaking off the outer bark while feeding on the larvae in the bark.

Blue-stain fungi introduced into the sapwood during successful attacks probably contribute to the rapid mortality associated with bark beetle attacks.

Woodpeckers, predaceous beetles and low winter temperatures provide natural control. Silvicultural activities that result in rapid, vigorous tree growth increases tree resistance and prevents mortality. Individual high value trees undergoing a temporary reversible stress, such as drought, can be protected for up to a year by applying insecticides to the bole.