Taxonomists have replaced the name Fomes annosus with *Heterobasidion irregulare* and *Heterobasidion occidentale*; all other information in this document is current.

Annosus Root Disease (*Heterobasidion annosum* (*Fomes annosus*))

Hosts: All conifers, Pacific madrone, manzanita

Distribution in California: Statewide

H. annosum conks in white fir stump

Photo: Pete Angwin

Characteristics: An annosus 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:

- 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

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

Photo: Pete Angwin

Wood decayed by *H. annosum* 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.

Annosus root disease infection center in ponderosa pine

Photo: Danny Cluck

Disease Cycle: Annosus 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 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 annosum in western North America consists of two intersterility groups, or biological species, the 'S' group and the 'P' group. These two biological species of *H. annosum* have distinct differences in host specificity. To date, all isolates of *H. annosum* from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense-cedar, western juniper, Pinyon, and manzanita are of the 'P' group. Isolates from true fir, Douglas-fir, hemlocks and giant sequoia are of the 'S' group. The biological species infecting other hosts are unknown at this time.

This host specificity is not apparent in isolates occupying stumps, with both the 'S' and 'P' groups recovered from pine stumps, and the 'S' group and occasionally the 'P' group from true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. However, while the S-group of *H. annosum* has been observed to pass from infected pine stumps into fir, it is very rare for the P-group of *H. annosum* to pass from infected fir stumps into pine. The fungus may survive in infected roots or stumps for many years. Young conifers of a species that is susceptible to the particular intersterility group established near these 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. Conks produce spores which disseminate throughout the year, but *H. annosum* is 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). Temperatures just below the stump surface commonly reach or exceed the thermal inactivation level (40º C) of mycelium from April to September in the Southeastern United States. 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.

Blowdown exposed *Annosus* root disease on the Plumas National Forest

Photo: Bill Woodruff

Stumps are susceptible to infection immediately

after cutting. Ponderosa pine, Douglas-fir, 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 compete with and replace *H. annosum*.

Vertical penetration depends on temperature and extent of injury from other sources. After germination, vertical penetration into pine stumps averages 3 inches/month from October through May and 5 to 6 inches/month from June to October.

Damage and Importance: Annosus 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.

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, annosus-infected trees are often extremely hazardous, causing death or injury to visitors, and damage to permanent installations and property. Ecologically, *H. annosum* 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.

Annosus root disease occurs on a wide range of woody plants. The disease affects all 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 annosus root disease. *H. annosum* 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 annosus 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 annosus-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 engravers (*Scolytus ventralis*)

Annosus root disease in incense-cedar and true fir is a problem in recreational areas. Whereas ponderosa and Jeffrey pines are usually killed by annosus before root systems are extensively decayed, incense-cedar and true fir usually have extensive decay in the roots before these trees die; therefore, these trees can fail while still living and therefore present a serious hazard.

Annosus root rot; Borax stump treatment

Photo: Paul Mistretta

Management Strategies: The goal of annosus 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 annosus root disease through detection, evaluation, prevention, and suppression. These activities must progress in a planned, timely sequence for successful reduction of annosus root disease impacts. Detection and evaluation in

individual stands are normally necessary before undertaking prevention and suppression action. In developed recreation sites, early recognition and removal of hazardous annosus-infected trees is critical, and will greatly improve chances of preventing future damage with minimal site deterioration. Prevention is the most desirable means of reducing losses. Undertake suppression activities only when needed to supplement prevention measures.

Management Strategies – Pine: Treat all freshly cut stumps in recreation areas with Sporax® (sodium tetraborate decahydrate, EPA Reg. No. 2935-501; see FSM 2303.14 R-5 Supp. 2300-92-1, 06/92 and FSH 3409.11.62.2.9 R5 Supp. 3409.11-94-1, 5/94). When infection levels are high, consider conversion to hardwoods. In all other areas, the appropriate line officer is responsible for the decision to treat freshly cut conifer stumps, and should consider treatments 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 annosus root disease currently in the stand or in nearby similar stands, determined by an examination of stumps for evidence of *H. annosum* and/or indications of infection in living trees.
- An estimate of the cost-effectiveness of the treatment.

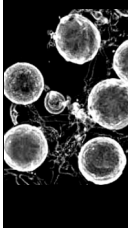
Forest Health Protection pathologists or CALFIRE pest management specialists can provide assistance.

Management Strategies – True Fir: Treat all freshly cut conifer stumps in recreation areas with Sporax®; 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 annosus 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®. However, if a group of true fir trees appear to be free of annosus 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, Forest Health Protection pathologists or CALFIRE pest management specialists can provide assistance.

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

- *H. annosum* can enter true fir in a stand by means other than through freshly cut stump surfaces
- True fir stands are often infested with *H. annosum* 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 aboveground crown symptoms produced.
- Sporax® treatment of true fir stump surfaces will not prevent the entrance of *H. annosum* 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. annosum* 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 annosus 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

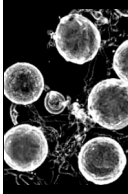
Enter the ratings into the following equation, then use the table on the following page to estimate root decay:

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



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