Forest Health Protection
Pacific Southwest Region

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To: District Ranger, Eagle Lake Ranger District, Lassen National Forest

Subject: Managing Annosus Root Disease in the Champs Project.
(FHP Evaluation # NE06-14)

At the request of Eagle Lake Ranger District, Dominic Cessmat (ELRD forester) and Bill Woodruff (FHP plant pathologist) surveyed part of the planned Champs Project on the Eagle Lake Ranger District for annosus root disease on September 26, 2006. The objectives were to survey for annosus root disease, caused by *Hetrobasidion annosum* and to provide management recommendations regarding stump treatment with SPORAX® to prevent annosus root disease. The Champs Project will treat vegetation and fuels along Forest roads in northern Eagle Lake RD west of and in the vicinity of Champs Flat.

The Champs Project area is forested primarily with ponderosa and Jeffrey pine in the overstory and understory. In some areas white fir grows amongst the pine, but essentially the project area is an eastside pine forest. Much of the white fir that is present today became established because fire suppression kept wildfire from burning ground vegetation in the project area. The overstory pine was logged in the last half of the 20th century. Many of the large pine stumps from the early harvesting became infected with *H. annosum.* Figure 1 shows a recently active annosus root disease center in the Champs Project which created an opening around 2 infected stumps approximately 0.10 acre in size. This disease is not common today in pine on the Eagle Lake RD primarily because for the last three decades the Lassen National Forest has been routinely treating freshly cut pine stumps with borax to stop *H. annosum* from infecting stumps and roots.

Figure 1. Annosus opening with older regeneration.

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No actively spreading annosus root disease was observed during this survey. The overstory ponderosa and Jeffrey pine trees in the Champs Project range in height from approximately 30-100 feet and DBH from 8-36 inches. The understory trees range from 2-30 feet in height. The management objective for the Champs Project is to create fuel breaks or DFPZ's (defensible fuel profile zones) to keep wildfire from burning across large amount of forest land.

Evidence of p-type (pine) annosus root disease was found in the form of stump decay characteristic of the disease. Two decomposed stumps, within the project area with advanced annosus-like decay, were dissected and no annosus fruiting bodies (conks) were found. Both stumps had live pine regeneration growing nearby, an indication that most of the *H. annosum* had died. Some older-dead seedlings and saplings were found near one of the stumps (Figure 1) suggesting that annosus root disease was recently active in some pine roots, even though mortality is not occurring at the edges of the annosus openings. Evidence of s-type (fir) annosus root disease was found in the form of characteristically decayed white fir roots on windthrown trees (see Figure 2).

Root contacts between trees within the Champs Project area are common pathways through which *H. annosum* can be transmitted tree-to-tree. In addition *H. annosum* can move long distances by wind-borne spores produced by the annosus conks growing on infected wood of dead pine or live fir trees many miles away. Airborne annosus spores can germinate on and infect freshly cut stumps and grow into uninfected roots. From there, the pathogen can spread through root contacts to roots of surrounding trees; eventually killing the pine. This tree-to-tree spread and mortality could continue indefinitely, as long as suitable host roots are available.

Figure 2. Annosus decayed roots on windthrown white fir

Annosus Root Disease Background

Worldwide in distribution, *H. annosum* is also widely distributed throughout the conifer forests of western United States. It has been found from the dry pinyon-juniper woodland of the Southwest to the wet cedar-hemlock forests of the Pacific Northwest. This fungus is indiginous and most abundant in the true fir forests (s-type annosus) of California.

The way in which the host is affected and the type of resulting damage may differ between hosts and regions. In pine, the fungus spreads from stumps through the root system, first attacking the inner bark and sapwood, killing these tissues. Its penetration into the heartwood is delayed. Within 2 to 6 years after initial infection, the fungus reaches the root crown and girdles the tree. The tree dies, but the fungus remains active as a saprophytic wood-decaying organism within the roots and butt of the dead tree.

Thus, in pine, p-type *H. annosum* usually kills the host within a short period. Pines weakened by *H. annosum* are often killed by bark beetles. In addition to pines, p-type annosus infects incense cedar, juniper, and a few shrubs.

In most other host species, the fungus seldom attacks the root tissues to the extent that the host is killed directly. In these hosts (eg. true firs, Douglas-fir and giant sequoia), the sapwood and inner bark usually are invaded only in the small-to-medium sized roots. The fungus is initially confined to the heartwood and inner sapwood of the larger roots. Within the heartwood, *H. annosum* spreads through the roots and root crown into the lower trunk of the host, where it causes a butt rot of the heartwood. Thus, infection in these species usually does not kill the host directly, although it may affect its growth or vigor. Lossed from *H. annosum* in true firs are mainly the result of butt rot, increased susceptibility to insect attack, and increased windthrow. Figure 3 shows dead and declining white fir trees, most likely infected with *H. annosum* and attacked by fir engraver beetles (*Scolytus ventralis*).

Figure 3. Dead and declining white fir

SPORAX® Background

Borate compounds have been successfully used for decades in the United States to prevent *H. annosum* stump infection. Originally, generic granular borax was used to treat freshly-cut conifer stumps to keep *H. annosum* from colonizing the roots. Borax, or sodium tetraborate decahydrate ($Na_2B_4O_7$ $10H_2O$), is a naturally occurring mineral which has been used more than 50 years in household laundry and cleaning, household insect control, hand cleaners and soil amendments to improve plant growth. Boron, a key element in borax, is an essential micronutrient for plant life, however high concentrations can be phytotoxic. Forestry use of borax was supplemented, about two decades ago, with the insecticide TIM-BOR®, disodium octaborate tetrahydrate ($Na_2B_8O_{13}$ $4H_2O$), which was applied to stumps as a liquid. Even though it is effective in controling annosus root disease, TIM-BOR® can no longer used in California because it is not registered for that application. When it became necessary to register borax to control annosus root disease in foretry applications, Wilbur-Ellis Corporation registered only the granular borax as SPORAX®. Essentially, SPORAX® is the same generic borax used for three decades in forestry and five decades in American homes and agriculture. The difference is that SPORAX® has been registered as an approved pesticide for control of *H. annosum*. Only SPORAX® can be used in California for this purpose. As with all pesticides, when using SPORAX® in forestry, this chemical must be purchased, stored, transported, and applied following all the applicable laws and regulations. This fact should be stated in planning documents and contracts pertaining to each project where SPORAX® is used.

Research has demonstrated that borax (both granular and liquid formulations) prevents the establishment and growth of *H. annosum* in freshly-cut stumps of conifers not

already infected. SPORAX® is a regulated pesticide which has been determined safe for use in forestry to treat conifer stumps by scientists and EPA. As an alternative to borates, biological agents have been used elsewhere in the world to control annosus root disease; but no biological control has been registered for use in California. Since both s-type and p-type annosus spores can occur in the Champs Project area, all freshly-cut conifer stumps 14 inches and larger in diameter should be considered for treatment with SPORAX®.

Management Alternatives for Annosus Root Disease in the Champs Project

Annosus root disease is present in the Champs Project area. *H. annosum* stump infections in pine and white fir could occur if freshly-cut stumps are not treated with SPORAX®. Treating fir stumps is only necessary if the stumps are not already infected and if the management objective is to retain healthy white fir.

Alternative 1. No Action.

The stand openings created in area by old pine-annosus stump infections will eventually become naturally reforested as seen in Figure 1. Without forest management, annosus root disease will persist in any infected true fir trees growing in the Champs Project area. Eventually *H. annosum* could infect healthy white fir trees through naturally-occurring wounds or root contacts. New annosus infections in ponderosa or Jeffrey pine will be rare because p-type/pine-annosus infection centers almost always originate from freshly created pine stumps. Over-crowded and/or diseased trees will continue to be killed by bark beetle events, often associated with precipitation deficits. Eventually, sufficient woody material from dead and dying trees might accumulate on the forest floor and in the canopy to provide fuel which could sustain ground or crown fires of varying intensities.

It should be noted, that even though annosus root disease kills p-type hosts and slows the growth of s-type hosts, *H. annosum* is an effective decay organism which decomposes conifer roots and recycles forest nutrients. *H. annosum* also can create hollows in stumps and roots which are sometimes used by small mammals for shelter. Additionally, forests with advanced decline and mortality due to annosus root disease will provide canopy openings which are beneficial for some species of wildlife and early-successional plant communities, including ponderosa pine, sugar pine and incense cedar. Also, snags and downed logs created by annosus root disease help sustain a wide variety of forest life. For this reason, depending on the management objectives for the Champs Project area, annosus root disease could be considered beneficial or detrimental to those objectives.

Alternative 2. Thin conifers and SPORAX® treat the freshly-cut stumps

Historically pine-annosus root disease has been active within the Champs Project area. Eastside conifer forests in the Lassen National Forest are reported to have high levels of annosus root disease in Forest Service Handbook R5 Supplement 3409.11. Therefore, treating newly created 14 inch and larger stumps with SPORAX® is recommended to prevent annosus root disease from infecting stumps and spreading to and killing a number of adjacent conifers. Infection with *H. annosum* could result in killing some large old-growth conifers in the project area over several decades.

Thinning over-stocked forests removes competing trees and makes soil moisture available to the remaining trees. With thinning the vigor and resilience of the residual trees can be improved, making them less susceptible to drought and bark beetle attack.

In a FHP study on the Lassen NF in eastside pine, it has taken about 30 years for annosus root disease to die off in overstory removal units where ponderosa pine roots became infected through stump infections. In these studies, natural pine regeneration near infected stumps began to become re-established about 30 years after seedlings around infected stumps were initially killed, indicating that most of *H. annosum* in the roots died. Now that the residual understory pine trees in the study area have grown to maturity, it is very important to treat freshly cut stumps with SPORAX® during future thinning projects. This is because the uniformly distributed large stumps remaining after the thinning would present ideal entry courts for *H. annosum* into an interconnected network of large roots which would be favorable for the survival and spread of *H. annosum*. Many large residual trees could be killed in the decades following a thinning as the disease spreads stump-to-tree and then tree-to-tree.

In the Champs Project area, it is recommended to SPORAX® treat all the freshly-cut pine stumps, 14 inches and larger, where the roots of those stumps contact other host trees. This is true for all p-type *H. annosum* hosts, including juniper and incense cedar. Once a ponderosa or Jeffrey pine tree is infected with p-type annosus, the tree will most likely die within few years, either directly from the infection or by subsequent bark beetle attack. If stumps are not treated with SPORAX®, mortality in post-thinning residual trees will be delayed by the time it takes for *H. annosum* to grow through the stumps and roots of cut trees to the roots and bole of adjacent trees. This process can take more than a decade, depending on many factors. Residual pine tree mortality can continue to occur as long as it takes for the pathogen to decompose all the roots; at least 30 years or more for ponderosa pine, depending on the root pathways present. Annosus root disease can continue spreading tree-to-tree in a mature pine forest indefinitely, as long as there are uninfected pines connected by root contacts to infected pines.

Treating uninfected stumps with SPORAX® is advised, since a stump surface is an ideal pathway to the roots for *H. annosum*; a pathway that is uncommon in nature. Choosing not to treat stumps will probably not totally decimate a conifer stand. Choosing not to SPORAX® treat 14 inch and larger stumps when thinning an old growth pine or mixed conifer stand will result in killing some of the large leave trees. The number killed depends on the size and species of the stumps and the distribution of s-type and p-type hosts.

Past experience with harvesting pine in California has shown annosus root disease to be more damaging in partial cuts than in clearcuts. This is because in clearcuts *H. annosum* can consume all available roots (nutrients) and die out before the planted trees reach maturity and make root contact with actively infected roots. Losing a few seedlings per acre to annosus root disease during the interim may not significantly impact the future stand. However, in selectively thinned stands of large pine trees, survival of the residual pine trees is much more critical since there are much fewer remaining after the thinning. A stand of mature pine could be significantly impacted by annosus root disease after a thinning where the 14 inch and larger pine stumps were not treated with SPORAX®. This is because each large stump is connected to an extensive root system which has a high probability of contacting one or more leave trees, thereby transmitting *H. annosum* if the stumps become infected.

Alternative 3. Thin all conifers without SPORAX® treating the freshly-cut stumps

Historically pine-annosus root disease has been active within the Champs Project area. Eastside conifer forests in the Lassen National Forest are reported to have high levels of annosus root disease in Forest Service Handbook R5 Supplement 3409.11. Therefore, treating newly created 14 inch and larger stumps with SPORAX® is recommended to prevent annosus root disease from infecting stumps and spreading to and killing a number of adjacent conifers. Infection with *H. annosum* could result in killing some large old-growth conifers in the project area over several decades.

As discussed in Alternative 2, tree mortality following thinning will be delayed by the length of the infection process. Initial mortality could occur in ponderosa pine as early as a decade after the freshly cut stumps are infected with *H. annosum* to as late as several decades. Once established, *H. annosum* will spread tree-to-tree through interconnected roots of s-type or p-type hosts, causing secondary and later tree mortality many decades after untreated stumps are first exposed. Some of the very large old growth ponderosa pine could be killed directly by *H. annosum* and some of the pine stressed by the disease could be killed by bark beetles.

It is impossible to predict the number of stumps that would become infected if not treated with SPORAX®. Past studies on the Shasta Trinity and Modoc National Forests have found between 3% and 17% of untreated 18 to 22 inch ponderosa pine stumps and between 8% and 35% of untreated 22 to 26 inch ponderosa pine stumps infected with *H. annosum* decades after the stumps were exposed. Pine stumps smaller than 14 inches did not appear to support *H. annosum* infections.

Again it should be noted, that even though annosus root disease kills p-type hosts and slows the growth of s-type hosts, *H. annosum* is an effective decay organism which decomposes conifer roots and recycles forest nutrients. *H. annosum* also can create hollows in stumps and roots which are sometimes used by small mammals for shelter. Additionally, forests with advanced decline due to annosus root disease will provide canopy openings which are beneficial for some species of wildlife and early-successional plant communities, including ponderosa pine, Douglas fir, sugar pine and incense cedar. Also, snags created by annosus root disease help sustain a wide variety of forest life. For this reason, depending on the management objectives for the Champs Project area, annosus root disease could be considered beneficial or detrimental to those objectives.

If you need further assistance, please contact Bill Woodruff at 252-6680. A short biology of annosus root disease and a copy of FSH R5 Supplement 3409.11-94-1 are attached to provide more information on annosus root disease.

/s/ ***Bill Woodruff***

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APPENDIX

Biology of Annosus Root Disease (*Heterobasidion annosum*)

Heterobasidion annosum is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridenta*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high on true fir in northern California campgrounds. Incidence is somewhat higher in older, larger fir stands and in stands with high basal areas (over about 330 square feet/acre).

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly cut stump surfaces or wounds on living trees. The fungus then spreads through root contacts into the root systems of adjacent live true fir. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.

In pines, *H. annosus* grows through root cambial tissue to the root crown where it girdles and kills the trees. In less resinous species such as true firs, the fungus sometimes kills trees, but more frequently it is confined to the heartwood and inner sapwood of the larger roots where it causes a chronic butt and root decay and growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its growth and thriftiness. Losses in true fir from *H. annosus* are mainly the result of windthrow resulting from root decay, and reduced root systems which predispose trees to attack and eventual death by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But when true firs slow in growth because of stand and/or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before tree death occurs.

Occasionally, infections will cross from roots of pine to roots of true fir; however, rarely is the fungus observed to cross from true fir to pine. At higher elevations where pine and true fir are intermixed, *H. annosus* is commonly found only on true fir and mortality rarely includes both species within an infection center.

FSH 3409.11 - FOREST PEST MANAGEMENT HANDBOOK
R5 SUPPLEMENT 3409.11-94-1
EFFECTIVE 5/17/94
CHAPTER 60 - MANAGEMENT OF SPECIFIC PESTS

62 - DISEASES.

62.2 - Other Diseases.

1. Introduction to Annosus Root Disease. This section describes annosus root disease in the Pacific Southwest Region, and discusses the biology and resource management implications of the disease. It also presents guidelines and techniques for its detection, and management strategies available for reducing its impact.

Annosus root disease is one of the most important conifer diseases in the Region. 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.

The goal of annosus root disease management in the Region 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. The basic guidelines for detection (FSM 3410), evaluation (FSM 3420), prevention (FSM 3406.1) and suppression (3406.2) for any insect or disease also pertain to annosus root disease. However, consider the additional specific guidelines for annosus root disease summarized in this section.

Annosus root disease occurs on a wide range of woody plants. The disease affects all western conifers; hardwoods are generally resistant or immune. All the National Forests in Region 5 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.

2. Biology. Heterobasidion annosum (Fomes annosus) causes annosus root disease. The fungus is similar to the common heartrot fungi, and forms fruiting bodies or conks in decayed stumps, under the bark of dead trees, or, rarely, under the duff at the root collar.

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. References that discuss the biology and disease cycle of H. annosum include Otrosina and Cobb 1989, and Smith 1993.

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 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. 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.

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. Surface area infection of freshly cut ponderosa pine stumps increases with increased photochemical oxidant injury.

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. The rate of vertical penetration in stumps from pine trees severely injured by photochemical oxidants is greater than in those from slightly injured or uninjured trees.

Heterobasidion annosum is an important agent predisposing conifers to bark beetle attack. In pines, the fungus weakens trees and increases their susceptibility to pine bark beetles. Infected true firs are predisposed to attack by the fir engraver. White fir mortality from the annosus root disease-fir engraver complex frequently occurs after tree growth decreases because trees are stressed. As a result of the stress, it is suspected that roots grow very slowly and decay faster than the tree can replace them. This predisposes the tree to fir engraver attack, and causes its death.

3. Detection. The general distribution of annosus root disease in the Pacific Southwest Region is known, but information on its location in specific stands may be needed. Based on Region-wide surveys, it is prudent to assume that the pathogen is present in all true fir stands, unless a detailed survey suggests that it is not. Collect location information for stands when planning management activities. Because trees affected by annosus root disease are easily windthrown or fall without visible symptoms that might warn forest recreation managers of impeding failure, the number, size, and locations of annosus infection centers within developed sites or sites planned for development should be determined. Field surveillance and detection surveys will locate occurrences of H. annosum.

4. Field Surveillance. Forest workers and managers, in connection with their regular duties, carry out day-to-day field surveillance (FSM 3411). Stand examinations, inventories and other activities afford excellent opportunities for forest workers to note and record the presence of H. annosum.

A systematic search for diagnostic symptoms of infection and signs of the pathogen, determines the presence of H annosum. Use the following similar symptoms for correct diagnosis:

a. Pattern of Dying Within the Stand. Root pathogens tend to kill trees over a period of years, with oldest deaths at the center, usually around stumps, and recently dead and dying trees at the margin. In contrast, a characteristic of mortality by bark beetles alone is groups of trees dying at about the same time.

b. Pattern of Dying of Individual Trees. Trees with root disease die gradually, with symptoms progressing from the bottom of the crown upwards, and from the inside of the crown out. Infection of the roots causes: (1) reduced height growth, with crowns becoming rounded; (2) thin and chlorotic crowns, resulting from poor needle retention; and (3) subsequent insect attack of the stressed trees.

c. Symptoms and Signs in Roots and Root Crowns. Use symptoms and signs in roots and root crowns to determine the specific identity of the pathogen. The best evidence of H. annosum is the presence of characteristic fruiting bodies or conks. The annual to

perennial, leathery conks vary in size and shape from small button-shaped or "popcorn" conks on the root surface of recently killed seedlings or saplings, to large bracket-type conks. The large conks generally have a light brown to gray upper surface, and a creamy white lower surface with regularly spaced, small pores. Small "popcorn" conks appear as small buff-colored pustules that range in size from a pinhead to a dime. They often have no pore layer. In pines, the conks are found between the bark and wood on stumps, beneath the duff layer at the root crown, and within old stumps. In true fir, the conks are found in cavities hollowed out by the fungus. Conks may be abundant in some stands and scarce or absent in others. Even when present, they can be easily overlooked because of their inconspicuous color and obscure location. Refer to Hadfield, et al. 1986 and Smith 1993 for color photographs of conks.

On pines, additional symptoms may be found by exposing the roots and root crown and examining the inner bark. Choose recently killed or dying trees for examination. Indications of H. annosum infection are: (1) easy separation of the bark from the wood; (2) the separated surfaces are a light brown to buff color, the surface of the wood streaked with darker brown lines; and (3) numerous small silver to white flecks on the surface of the inner bark. Resin often heavily infiltrates infected roots.

Incipient or early stages of wood decay are not very diagnostic. Discoloration may or may not be present and the heartwood remains firm and hard. As the decay progresses, the wood becomes white to straw yellow, separates along annual rings, and may contain elongated white pockets.

If field personnel are unable to identify H. annosum with certainty, or desire confirmation of a tentative identification, the Forest Pest Management Group can assist. Gather specimens of infected root tissue in various stages of decay and any fruiting bodies and send them to FPM pathologists in the Service Areas, or to pathologists in the Regional Office. The specimens must be of tissues in early stages of decay to enable isolation of the pathogen. A completed Forest Pest Detection Report (Form R5-3400-1) shall accompany the samples.

5. Detection Surveys. Personnel may conduct detection surveys (FSM 3412) in areas where no other surveys are scheduled and it is essential that the presence or absence of annosus root disease be known for management purposes. The objective of a detection survey is simply to determine the presence and location of H. annosum.

Because annosus root disease is not always obvious and can be difficult to detect, contact the Forest Pest Management Group with a request to conduct the survey if H. annosum has the potential to adversely affect activities or interfere with resource objectives.

6. Evaluation. The purpose of a biological evaluation (FSM 3421) is to provide information for the resource manager on annosus root disease infestations, their affects on the stand, the management alternatives appropriate in the context of the particular resource management objectives, and the future affects of each alternative. The Forest Pest Management Group or field personnel shall conduct biological evaluations of annosus root disease. Submit requests for a biological evaluation by sending a Forest Pest Detection Report (Form R5-3400-1) or written request to the Regional Forester or FPM Program Leader, or to one of the Service Areas. Field units shall coordinate requests through the appropriate line officer.

7. Management Strategies. Use the integrated pest management (IPM) approach to manage annosus root disease and other pests. IPM involves regulating the pest, the host, and the environment to minimize pest impacts on resource management objectives in ecologically and economically sound ways. Also, use the IPM approach to implement and coordinate activities needed to prevent or suppress pest-related problems. This approach also emphasizes the selection, integration, and use of a variety of tactics on the basis of anticipated economic and ecological consequences. Accomplish control of annosus root disease by prevention of new disease centers, thereby decreasing the risk of stump and wound infection, and through silvicultural manipulation of infested stands to minimize the impact of the disease.

8. Prevention. Prevention (FSM 3406.1) includes activities designed to minimize the impact of a pest before it appears. The objective of annosus root disease prevention is to prevent establishment of the disease in stands. Once annosus root disease becomes established in most forest stands, no economically feasible procedure for directly suppressing the disease is available. Therefore, prevention is the most efficient and economical method of reducing the impact of H. annosum. Prevention of annosus root disease includes treatment of freshly-cut conifer stumps with registered products. Other preventive treatments include carrying out silvicultural activities to lessen stand susceptibility to the disease, and minimizing logging damage and mechanical injuries.

9. Stump Treatment. Personnel can reduce the probability of infection of freshly cut conifer stumps by the use of a surface stump treatment with registered products. Contact Forest Pest Management for currently registered and effective materials. Treatment of freshly cut conifer stumps with two borate products (sodium tetraborate decahydrate and sodium octaborate tetrahydrate) indicate at least 90% efficacy in preventing infection. The borate in the formulations is toxic to the spores of the fungus and prevents germination; it does not have an effect on existing infections. Apply the products according to label directions. For maximum effectiveness, it is imperative to apply the material as soon after felling as practical and that the application cover the entire stump surface and other areas where the bark has been knocked off. The requirement for application in timber sales and other non-force account work shall be part of the contract or cooperative agreement. A Regional C provision is available for inclusion in timber sale contracts.

R-5 FSM 2303 requires treatment of all conifer stumps in recreation sites. The same direction shall apply to other high value areas, such as progeny test sites, seed orchards, and areas of high value trees, such as giant sequoia groves. In eastside pine or mixed conifer type stands, where surveys have indicated high levels of annosus root disease, treatment of conifer stumps 12 inches ***(Note: Revised to 14 inches: Ref. Kliejunas & Woodruff, FHP Report # R04-01)*** or greater in diameter is highly recommended during chainsaw felling. When mechanical shearers are used, the minimum diameter should be reduced to 8 inches ***(also revised to 14 inches)***. These areas include the eastside pine and eastside mixed conifer types on the Modoc, Lassen, Plumas, Tahoe, Sequoia and Inyo National Forests; the Goosenest Ranger District, Klamath National Forest; and the McCloud Ranger District, Shasta-Trinity National Forests.

In all other areas, consider stump treatments on an individual stand basis. The line officer is responsible for the decision to treat freshly cut conifer stumps, and shall base that decision on information available for the specific situation in the particular stand in question. This information should include:

a. The objectives and management direction for the stand.

b. 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 indications of infection in living trees.

c. An estimate of the cost-effectiveness of the treatment.

d. A Forest Pest Management biological evaluation or an on-site visit.

10. Avoiding Cambial Damage. In addition to being an aggressive colonizer of freshly-cut stumps, H. annosum can also act as a wound parasite by attacking living trees through injuries that expose cambial tissue. The fungus, as well as other decay fungi, are likely to colonize logging injuries, especially those in contact with the ground. Trees with nonresinous wood, such as true fir and hemlock, are more likely to be infected following injury and to have more extensive decay than species with resinous wood, such as Douglas-fir and the pines. Decay caused by H. annosum is common behind fire scars and other basal wounds in true fir. It may be possible to minimize losses by preventing fires that expose cambium when underburning for fuels reduction, and by reducing mechanical injuries during stand entries.

Other methods of prevention have been suggested, but consider these methods experimental until there is demonstrated efficacy under California conditions. These experimental methods include: (1) thinning during the hotter summer months; (2) creation of high stumps, and, (3) control of stocking density in true fir stands.

11. Suppression. Suppression (FSM 3406.2) of annosus root disease includes the reduction of damage to acceptable or tolerable levels. Direct suppression procedures for H. annosum, such as stump removal, creation of buffer strips, and soil fumigation, are costly and considered experimental. Indirect suppression options, that is, those that alter conditions favoring the pest through the application of silvicultural methods of stand manipulation, are available. These methods include species conversion, thinning in true fir stands, and in recreation areas, thinning and interplanting with hardwoods.

a. Species Conversion. Because of host specificity of the 'S' and 'P' types of H. annosum, favor the non-infected host species (see item 2.a.). In mixed conifer stands with infected true firs, the stand my be converted to pines and incense-cedar with little risk of subsequent infection. If pines are infected, favor true fir. In recreation areas, favor existing hardwoods or the non-infected conifer species. Since hardwoods are resistant, the fungus will eventually die out over a period of 2 to 4 decades, depending on stump size. Then, take steps to regenerate the conifers.

b. Thinning in True Fir Stands. Field observations suggest that removal of slow growing fir and thinning of overstocked stands to increase tree vigor may reduce the impact of the disease, given that the residual trees are capable of responding to release.

c. Revegetate Disease Centers. If consistent with site-specific objectives, resistant species can be used to revegetate active annosus centers. Leaving the centers barren or revegetating with hardwoods will allow the fungus to eventually die out over a period of several decades or more. Favoring hardwoods already present and planting suitable

hardwoods provides a barrier of nonsusceptible roots that may limit the spread of infection centers. Thin dense pole-sized stands of susceptible conifers and interplant with hardwoods. Doing this minimizes opportunities for root contact and reduces the risk of further spread. It also increases tree vigor, which reduces risk of bark beetle attack.

d. Stump Removal. Removal of stumps and roots infected with H. annosum would reduce the amount of inoculum of the fungus on the site, and allow for earlier successful revegetation of the site with susceptible conifers. Stump removal as a suppressive method is being tested in several recreation sites, and its efficacy has not yet been demonstrated.

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