FOREST SERVICE HANDBOOK PACIFIC SOUTHWEST (R5) VALLEJO, CA

FSH 3409.11 - FOREST HEALTH PROTECTION HANDBOOK

CHAPTER 60 - MANAGEMENT OF SPECIFIC PESTS

Supplement No.: 3409.11-2013-1

Effective Date: June 10, 2013

Duration: This supplement expires 10 years from the effective date unless superseded or removed earlier.

Approved: RANDY MOORE
Regional Forester

Date Approved: 6/10/2013

Posting Instructions: Supplements are numbered consecutively by Handbook number and calendar year. Post by document; remove the entire document and replace it with this supplement. Retain this transmittal as the first page(s) of this document. The last supplement to this Handbook was 3409.11-2010-1 (2/09/2010) to 3409.11_60.

Last Change: 3409.11_10-2013-6 to Chapter 60

New Document: 3409.11-2012-1, 19 Pages

Superseded Document(s): 3409.11-2010-1 2/09/2010, 16 pages

Digest:

Section 64 was added to this supplement.

62 - DISEASES

62.2 - Other Diseases

1. Introduction to *Heterobasidion* (Annosus) Root Disease and Summary. This section describes *Heterobasidion* root disease (HRD) in the Pacific Southwest Region, and discusses the biology and resource management implications of the disease. It also presents sampling guidelines and techniques for detecting the fungus, and management strategies available for reducing its impact.

   HRD is one of the most important conifer diseases in the Region. According to current estimates, the disease infests about seven million acres of commercial forest land in California (Smith, 1984) causing an estimated annual volume loss of 19 million cubic feet. Potential impacts of the disease include increased likelihood of mortality during drought, increased susceptibility to bark beetle attack, increased susceptibility to windthrow, loss of wood production, mortality of infected trees, and loss of vegetative cover. In addition, disease-caused windthrow in recreation areas can be highly hazardous, leading to injury or even death of visitors or damage to permanent installations and property.

   Over the past 160 years, HRD has increased its distribution and impact across most coniferous forests of the Pacific Southwest because selective cutting and partial cutting have created opportunities for the spores of *Heterobasidion* spp. to colonize the freshly cut stumps which, in turn, has led to the establishment of many new infection centers. Surveys show that almost all coniferous forests in California have at least low levels of the disease or are close enough to infested forests to receive live spores of the pathogen. Unless measures are taken to prevent spread of the pathogen, the disease will continue to spread and intensify, causing unacceptable impacts.

   The goal of HRD management in the Region is to prevent mortality and growth losses from exceeding levels which are economically, aesthetically, and environmentally acceptable when measured against the multiple objectives and constraints of resource managers. Detection and evaluation in individual stands are advisable before prevention and suppression actions are initiated. *Forest Pathologists in the Forest Health Protection (FHP) Shared Service Area Offices can assist with these activities*. Several actions that can be undertaken to reduce the incidence of new infection centers are explained in the management section of this handbook, including best practices to follow when applying borate compounds to freshly cut stumps.

   The decision of whether or not to apply borax compounds is the responsibility of the line officers. Decisions made with respect to HRD can substantially influence the condition of the forest for the next several hundred years. One of the main objectives of this handbook is to provide Forest Supervisors and their line officers with the best information available, so that well-informed decisions may be made with respect to the wise management of this disease.

2. Biology and Impact. Several *Heterobasidion* species (formerly considered a single species, *Heterobasidion annosum* a.k.a. *Fomes annosus*) cause HRD. This group of closely related fungi is similar to common heart-rot fungi and forms fruiting bodies or conks in sheltered locations such as inside decayed stumps, under the bark of dead trees and under the duff at the root collar. Abundant spores are produced from the porous white under surfaces of these conks. The fungus can also produce an asexual spore stage (a Spiniger, a.k.a., Oedocephalum stage) directly from the fungal hyphae as it colonizes rotting wood and roots. Both spore stages are air-borne.

New infection centers typically are initiated when airborne *Heterobasidion* spores land and grow on the surfaces of freshly cut conifer stumps in uninfected stands. Infection in true fir may also occur through fire and mechanical wounds on the tree's butt, however, fresh basal wounds on species other than true fir are rarely colonized. Once it is established, the fungus grows down the stump into the roots and then spreads from tree to adjacent trees through root contacts. Infection-centers, called foci, continue to enlarge until they reach natural restrictions to further root colonization, such as openings in the stand or the roots of *Heterobasidion*-resistant plants. In pines, the fungus utilizes root cambial tissue to grow into the root crown where the fungus girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees outright; but colonization is more frequently concentrated in the heartwood and inner sapwood of larger roots. Chronic root decay causes growth loss and eventually extends into the heartwood of the lower trunk where it weakens roots to the point where they fail to keep trees upright. Additional information on the biology and disease cycle of *Heterobasidion* species is provided in Otrosina and Cobb 1989, and Smith 1993.

Until thirty years ago, *Heterobasidion* spp. was considered a single species. In 1978, Kerhonen (1978) determined that isolates fell into two distinct intersterility groups (ISGs). More differences between isolates from these groups were found using allozyme analysis Otrosina et al. (1992) and other techniques (Garbelotto et al., 1996; Otrosina and Cobb, 1989), and, finally Otrosina and Garbelotto (in press), have been able to make a clear distinction between the two species of *Heterobasidion* found in forests of California using both molecular genetic techniques and morphological traits,. They have named these fungi *Heterobasidion irregulare* (which had temporarily been referred to as the 'P' (Pine) type) and *Heterobasidion occidentale* (which had temporarily been referred to as the 'S' (Spruce/fir) type). As a simple rule, *Heterobasidion irregulare* can kill ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense-cedar, western juniper, and pinyon pine, while H. *occidentale* can kill true firs, hemlock, Douglas-fir, and giant sequoia. In spite of the proven differences between these two *Heterobasidion* species in California, they are still very closely related and their biology is so similar that in this document, except during the explanation of two management possibilities, there will be limited further distinction between them and the disease that they cause will simply be referred to as HRD.

HRD can affect a wide range of woody plants including most species of western conifers. Most hardwoods are resistant or immune (madrone may be an exception).

All National Forests in Region 5 have reported this disease. Incidence is particularly high on Jeffrey pine in southern California recreation sites that have had a history of tree removal and on Jeffrey and ponderosa pine in eastside pine-type forests. The disease is endemic in the red and white fir forest types, and surveys in northern California show that it is a factor in one-fifth or more of the mortality of true fir in these forests.

Host specificity does not hold true during colonization of stump surfaces and roots. Both *Heterobasidion irregulare* and H. *occidentale* isolates are recovered from pine stumps, and H. *occidentale* and occasionally H. *irregulare* are recovered from true fir stumps. Although saprophytic colonization of stumps is not type-specific and the fungus can survive in colonized roots or stumps for many years before coming in contact with a host, only tree species that are susceptible to the specific type of isolate in a given stump can become infected through root contact when they grow into contact with this inoculum. When this does happen, however, colonization and death can be swift. For example, young susceptible conifers that establish near such stumps often die within three years of contact with colonized wood.

Colonization 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 *Heterobasidion* spores are dependent on favorable environmental conditions for successful germination and establishment. Spores are inactivated at ambient temperatures of 113° F (45°C), and mycelium in wood is killed after exposure to 104° F (40° C) for one hour (Korhonen and Stenlid,1988).

Thermal inactivation is a key factor to consider when designing management strategies for this aggressive fungus. In the southeastern United States, temperatures just below the cut surface of the stump commonly reach or exceed the mycelium's thermal inactivation limit (40° C) from April to September. For pines in the Lassen National Forest on the east side of the Sierra crest in an average summer, temperatures reach the lethal 40° C in the top 6 inches of 6-inch diameter stumps after exposure to direct sunlight for several days (Smith, unpbl.). 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 probably results from colonization of the stumps by other microorganisms that compete with and replace *Heterobasidion*. Vertical penetration of fungal hyphae into stumps depends on temperature and extent of tree injury from other sources. In ponderosa pine stumps, the rate of vertical penetration averages 3 inches/month from October through May and 5 to 6 inches/month from June to October. The rate of vertical penetration in pine stumps from trees with foliage severely injured by photochemical oxidants (these oxidants are commonly found in smog) was greater than in pine stumps where photochemical injury to foliage had been slight or nil (James et al., 1980).

Heterobasidion is an important stress-causing agent and its negative impacts on root systems result in predisposing conifers to bark beetle attack. In firs severely affected by HRD, the water absorbing and conducting parts of the root system are progressively diminished and eventually water lost to transpiration cannot be replaced at a fast-enough rate. This leads to moisture stress, especially towards the top of the tree, and predisposes the tree to fir engraver attack. In pines affected by this disease, root systems are similarly impacted and the trees· become more susceptible to pine bark beetles.

Whereas slowed growth, predisposition to drought and bark beetles, and an accelerated accumulation of down woody material may be reasons to be concerned about having HRD in stands of the general forest, in forest recreation areas, there are added reasons for concern: *Heterobasidion*-affected trees, which often show no visible symptoms, pose a high danger of falling on people or structures.

3. Detection. The general distribution of HRD in the Pacific Southwest Region is known, but information on its location in a specific stand 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. There are several ways of determining whether the root disease is present

4. Field Surveillance. Forest workers and managers, in connection with their regular duties, can carry out day-to-day field surveillance (FSM 3411). When conducting routine stand examinations, such as inventories, there are often excellent opportunities for forest workers to note and record the presence of HRD. Symptoms and signs can be used to help in the diagnosis and for delimiting the areas (foci) where the disease is having an impact:

   Symptoms of HRD.

a. Pattern of Dying Within the Stand. Root pathogens tend to kill trees in patches (foci) and over a period of years. Because of the way disease progresses through root contact, the oldest tree deaths tend to be at the center of these foci (and usually around stumps) and the most recently dead and dying trees are found at the margin. (Note: by contrast, a characteristic of mortality by bark beetles alone is groups of trees all 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. Since roots become rotted by *Heterobasidion*, another characteristic of affected trees is that they are much more prone to windthrow, especially those species affected by *Heterobasidion occidentale*. Therefore, when stand-s show evidence of windthrow, *Heterobasidion* should be considered as a possible contributing agent.

d. Check the wood at the base of the tree or the affected roots (or in the stumps) to see if they have the pattern of decay that is characteristic of *Heterobasidion*. On pines, common symptoms of *Heterobasidion* decay include the following: (1) easy separation of the bark from the wood; (2) the separated surfaces are a light brown to buff color often with 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. In addition, resin often heavily infiltrates infected roots.

The degree to which the decay has progressed has an important effect on the degree to which any of these symptoms might be expressed. During the incipient or early stages of wood decay by *Heterobasidion* diagnosis is difficult; discoloration may or may not be present and the heartwood remains hard. As the decay progresses, however, the wood becomes white to straw yellow and can be separated easily along annual rings. At an advanced stage, the affected wood may contain elongated white pockets.

Signs of annosus. It is worth noting that other root diseases (such as those caused by *Armillaria ostoyae* (shoe-string root rot), *Phellinus weirii* (laminated butt rot) and *Leptographium wageneri* (blackstain) can cause similar symptoms described in (a), (b) and (c) above, so when the symptoms, described above, are observed, additional efforts should be made to see if signs of *Heterobasidion* (ie. parts of the fungus, itself), and especially fruiting bodies, can be found.

The best evidence of *Heterobasidion* species is the presence of their 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 on bigger trees. The large conks generally have a light brown to gray upper surface, and a creamy white lower surface with regularly spaced; small, round pores. Small "popcorn" conks can also 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.

Sometimes, even when it is obvious that a root-rotting pathogen is present, it is impossible to find any conks of the fungus and the wood decay pattern may also not be definitive enough to make a confident identification of the particular root rotting pathogen.

In such cases, a section of wood from the affected stump or roots can be cut and placed in a plastic bag with a little water (a moistened paper towel will provide enough water). After seven to ten days, if *Heterobasidion* is in the wood, the development of conidial fruiting structures belonging to the *Oedocephalum lineatum* (aka *Spiniger meikeckellus*) stage of this fungus will emerge on the surface of these samples. This is another conclusive sign that the stump is infected with *Heterobasidion* spp.

e. Symptoms and Signs in Roots and Root Crowns: If field personnel are unable to identify HRD with certainty, or desire confirmation of a tentative identification, Forest Health Protection (FHP) can assist. Gather specimens of infected root tissue in various stages of decay, and any fruiting bodies found, and send them to FHP pathologists in the Service Areas of the USFS Supervisors Office in Redding, Susanville, Sonora or San Bernadino, or to the pathologist in the Regional Office (in Vallejo). (Note: woody tissue specimen· s should be in the early stages of decay to enable isolation of the pathogen.) A completed Forest Pest Detection Report (Form RS-3400-1) should accompany the samples.

5. Detection Surveys. Personnel may conduct special detection surveys when it is essential for the presence or absence of HRD to be known for management purposes.

   HRD is not always obvious. When this is the case, and because the presence or absence of *Heterobasidion* greatly influences the management options that might be recommended.in a given stand, it may be advisable to contact a FHP Forest Pathologist at a Shared Service Area to help conduct a survey.

6. Evaluation. There are several types of evaluations that can be conducted for HRD. The most common is a biological evaluation. The purpose of a biological evaluation (FSM 3421) is to provide information for the resource manager on HRD infestations in the stands of interest, their general effects on stands, the management alternatives appropriate in the context of the particular resource management objectives, and the future effects of each alternative. On request, the local FHP Shared Service Area pathologist will conduct biological evaluations for HRD. Submit requests for a biological evaluation by sending in a Forest Pest Detection Report (Form RS-3400-1) or by simply writing a request to FHP personnel at the indicated Service Areas.

   Sometimes a more in-depth evaluation might be needed. For example, it may be desirable to know the exact distribution of HRD in a stand or landscape, or to know the amount of volume loss that has taken place as a result of this disease. In other cases, it may be of interest to know what losses- might occur from this disease in the future with and without certain stand treatments. The FHP pathologist can help with all of these queries. However, the last of these may also require the services of an analyst competent in Forest Vegetation Simulation (FVS) and familiar with the Western Root Disease Model (Frankel, 1998).

7. Management Strategies. Use an integrated pest management (1PM) approach to manage HRD and other pests. 1PM can involve regulating the pest, the host, and/or the environment to minimize pest impacts on resource management objectives in ecologically and economically sound ways.

   Suppression activities can be undertaken to supplement prevention measures. The basic guidelines for detection, evaluation, prevention and suppression for any insect or disease also pertain to HRD and are available in Chapter 3410 of the FSM (sections 3411-3419). However, additional guidelines specific for HRD are summarized in this section of this handbook. These activities must occur in a planned and timely sequence if impacts are to be well controlled.

   ln developed recreation sites, early recognition of hazardous *Heterobasidion*-infected trees is critical. The early removal of obviously infected trees, along with adjacent less-severely infected trees, will greatly improve chances of preventing future damage and will minimize site deterioration.

8. Prevention. Prevention is the most desirable means of reducing losses caused by *Heterobasidion* spp. The objective of HRD prevention is to prevent establishment of the disease in stands that are as yet uninfected. Once the disease becomes established in most forest stands, there are no inexpensive procedures for directly suppressing the disease. Therefore, prevention is the most efficient and economical method to reduce impacts.

   Preventive treatments may include implementing silvicultural activities to lessen stand susceptibility to HRD and minimizing logging damage or other injuries. However, many silvicultural activities leave some stumps behind; therefore, prevention of HRD usually includes treatment of freshly cut conifer stumps with registered pesticides.

   a. Stump Treatment. The probability of infection of freshly cut conifer stumps can be reduced by applying a registered borax fungicide (for example, Sporax®) soon after the tree is felled. Studies indicate at least a 90% efficacy in preventing infection under conditions that would otherwise have led to stump colonization by *Heterobasidion* spp.

      The borate in borax is toxic to recently germinated spores of this fungus but it does not have an effect on existing infections. Therefore, for maximum effectiveness, it is imperative to apply the borax as soon after felling as practical and certainly within 4 to 24 hours after the tree is felled (Cobb and Barber, 1968). It should be recognized that the chances of spores landing on a stump and germinating will progressively increase as those initial hours pass. If two days pass, there is no longer any point in applying borax; if conditions have been favorable, stump colonization will already have taken place.

      The borax, when applied properly, should cover the entire stump surface with a thin layer and other areas of the stump where the bark has been knocked off. By "thin layer", what is meant is that the borax should be applied evenly across the stump in such a way that it is easy to see from about 10 feet away (at least until it rains), but also so that nowhere is the thickness of this layer more than that of a couple of granules. On average, this will work out to about one pound of borax for every 50 square feet of basal area (or stump surface) being treated. Where a liquid form of borax is being used, the spraying of a thin film of the solution on the stumps surface is all that is needed. A dye mixed in with this solution, is useful to show where stumps have been sprayed.

Handling directions are provided on the labels of borax containers and should always be followed. Also, refer to FSM 2150 and FSH 2109.14 for pesticide use policy and direction. Only pesticides registered in California can be used on the National Forests within Region 5, and all Forest Service policies and practices and California regulations relating to pesticide use must be followed. 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.

Trees thinned by masticators often leave a ragged stump surface. This makes it more difficult to get complete application of borax granules. When a liquid formulation of borax registered for the control of *Heterobasidion* is available it may be preferable because these masticated surfaces may be better protected by a liquid formulation. The general instructions would be to apply the spray to cover the entire cut surface of the stump just short of the point of runoff.

Because of the high value of residual trees in developed recreation areas, and especially the importance of minimizing the development of hazard trees in these areas, it is recommended that in developed recreation areas all conifer stumps greater than 3" across (outside bark diameter) receive borax at the time the stump is created. Stumps of smaller diameter conifers may also be treated, and it may be simplest to issue contracts that call for the treatment of all conifer stumps in developed recreation areas, but inoculum will not survive long in the root system of these small stumps, so it is not critical that they receive borax. The same directions shall apply to other high value areas, such as progeny test sites, seed orchards, and other areas where there are high value trees, such as in the giant sequoia groves.

Note: The.re may be recreation areas that have extensive boundaries (eg ski areas) within which cutting for fuels reduction or barkbeetle risk reduction might be conducted. Where these cutting activities occur within the parts of the recreation area where recreation facilities or visitor use are not concentrated, the line officer, in consultation with the FHP pathologist, may use his/her discretion to apply borax in accordance with recommendations for the general forest (see ahead).

In eastside pine or mixed conifer-type stands in the general forest (forest stands that are not in recreation areas or other high-value areas), and especially in areas where surveys have indicated light or moderate levels of HRD, treatment of conifer stumps 14 inches or greater in diameter (outside bark) is recommended. 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 (Note: in the context of this document, eastside refers to areas in California which are east of a straight line which passes from Lake Tahoe to the intersection of Interstate 5 with the California-Oregon border).

In all other areas of California, 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:

(1) The objectives and management direction for the stand. (For example, if the forest is being managed for wildlife, then *Heterobasidion occidentale* may not be objectionable in the

stand because it will lead to the formation of many snags with cavities; however, if timber production or recreation or the creation of old-growth stands is the objective, then any kind or amount of HRD may be objectionable. Indeed, in recreation areas, trees that are infected with *Heterobasidion* spp. are, or may soon become, hazard trees).

(2) The level of HRD currently in the stand or in nearby similar stands, determined by an examination of stumps for evidence of *Heterobasidion* and/or indications of infection in living trees. (Note: if reliable surveys or biological evaluations conducted now, or in the past, indicate the disease is not present in the stand being managed, nor in neighboring stands that are within several miles, then there is no need to take preventative measures (e.g. apply borax) to prevent infection of cut stumps. On the other hand, if there is light to moderate infection in the stand being considered or in neighboring stands (e.g. 2% to 40% of the examined stumps in these stands show evidence of the disease) then it is especially critical to prevent the *Heterobasidion* from colonizing newly created stumps (during thinning operations, partial cuts, etc); Finally, if the colonization of existing stumps is already heavy throughout the stand in question (40% to 100% of the stumps already have *Heterobasidion*), then the whole area of that stand is considered infested and there is little point in trying to prevent infection of newly created stumps.

Over the past decade, a massive sampling effort has been undertaken to try to evaluate the number of *Heterobasidion* spores in the air throughout the entire range of California coniferous forests and during all seasons; When this study is complete, it will provide extremely valuable additional information for deciding where and when coniferous stumps would, in the absence of applied borax, run the greatest risk of becoming colonized by *Heterobasidion* spp.

(3) An estimate of the cost-effectiveness of the treatment (it is worth indicating that in developed recreation sites, where people are camping, picnicking or living, these analyses usually come out very strongly in favor of taking aggressive preventive action because of the very high value of human life (Wood et al., 1979, Parmeter et al., 1978)). Failure to successfully manage HRD in developed recreation areas can lead swiftly to closure of the affected recreation site. In the general forest (outside developed recreation areas), managers may also be interested in preventing HRD. Fortunately, the application of adequate amounts of borax has been shown to be as inexpensive and often a cost-effective means of providing adequate protection against stump colonization even in the general forests, Kliejunas (l989).

(4) A site visit by a Forest Health Protection specialist with findings documented in a biological evaluation/report.

b. Avoiding Cambial Damage. In addition to being an aggressive colonizer of freshly-cut stumps, *Heterobasidion* can also act as a wound parasite by attacking living trees through injuries that expose cambial tissue. Trees with non-resinous wood, such as true fir and hemlock, are more likely to be infected following injury and have more extensive decay than species with resinous wood, such as Douglas-fir and pines. Decay caused by *Heterobasidion* is common behind fire scars and other basal wounds in true fir. It may be possible to minimize losses by preventing damage to cambium at the base of the trees when under-burning for fuels reduction (for instance by doing

controlled burns during cooler or wetter periods of the year or by removing needle litter from around the base of trees), and by reducing mechanical injuries to the cambium during harvesting or thinning operations.

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; and (2) creation of high stumps.

9. Suppression. Suppression of HRD includes the reduction of damage to acceptable or tolerable levels. Direct suppression procedures, 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 also available. In the general forest these methods include species conversion and thinning in true fir stands. In recreation areas, they include thinning and inter-planting with hardwoods.

    a. Species Conversion. Because *Heterobasidion occidentale* and H. *irregulare* affect different specific hosts, knowing which species of *Heterobasidion* is present and then favoring non-susceptible hosts offers one possibility for control. In mixed conifer stands with infected true firs, the stand may be converted to pines and incense-cedar with little risk of subsequent infection. Conversely, if pines are infected in an area, true fir could be favored. In recreation areas, favor existing hardwoods or the non-infected conifer species. Since hardwoods are resistant to *Heterobasidion*, if only hardwoods are left after a thinning the fungus will die out over a period of 2 to 4 decades (depending on stump size). After that, steps could be taken to regenerate with conifers.

    b. Thinning in True Fir Stands. In overstocked stands of young fir, field observations from some studies suggest that thinning at a young age may increase vigor of the residual trees sufficiently to reduce the impact of the disease (Smith, 1983; Kliejunas, 2004).

    c. Revegetate Disease Centers. If consistent with site-specific objectives, resistant species can be planted or allowed to regenerate naturally. If at least four decades pass, the *Heterobasidion* will die out in *Heterobasidion* centers treated in this manner.

    d. Stump Removal. In some situations, such as recreational areas, the high- cost of removal of *Heterobasidion*-infected stumps, using heavy equipment, may be justified.

10. Final Observations: Of all the pathological agents operating in the forests of California, *Heterobasidion* is among the most destructive. It is already widespread in coniferous forests in much of the state and partial cutting practices, now prevalent in the general forest and in all recreation areas, will continue to facilitate further spread of this fungus unless the detection and preventive measures, detailed in this handbook, are followed carefully. Forest Service FHP employees are available to help with detection surveys in all Shared Service Areas.

REFERENCES

Cobb, F. W. and H. W. Barber. 1968. Susceptibility of freshly cut stumps of redwood, Douglas fir and ponderosa pine to *Fomes annosus*. Phytopathology 68:1551-1557.

Frankel, S.J. 1998, technical coordinator. User's guide to the Western Root Disease Model, version 3.0. Gen. Tech. Rep. PSW-GTR-165. Albany, CA: Pacific Southwest Research Station, U.S. Department of Agriculture; 164 p.

Garbelotto, M., A. Ratcliff, T.D. Bruns, F.W. Cobb, and W. J. Otrosina. 1996. Use of taxon-specific competitive-priming PCR to study host specificity, hybridization, and intergroup gene flow in intersterility groups of *Heterobasidion annosum*. Phytopathology 86:543-551.

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

James, R.I., F.W. Cobb, W.W. Wilcox and D.L. Rowney.1980. Effects of phytochemical oxidant injury of Ponderosa and Jeffrey Pine on susceptibility of sapwood and freshly cut stumps to *Fomes annosus*. Phytopathology Vol. 70, No. 8 pp704-708.

Kliejunas, J.T. 1989. Borax stump treatment for control of annosus root disease in the Eastside Pine Type Forests of Northeastern California. USDA Forest Service, Gen. Tech. Rep. PSW-116.

Cobb, F.W. and H.W. Barber. 1968. Susceptibility of freshly cut stumps of redwood, Douglas-fir and ponderosa pine to *Fomes annosus*. Phytopathology 68:1551-1557.

Kliejunas, J. and B. Woodruff. 2004. Pine stump diameter and Sporax® treatment in eastside pine stands. Report No. R04-0l. Forest Health Protection Pacific Southwest Region. USDA Forest Service. 6 p.

Korhonen, K. 1978. Intersterility groups of *Heterobasidion annosum*. Commun. Inst. For. Fenn. 94:1-25.

Korhonen, K. and J. Stenlid. 1988. Biology of *Heterobasidion annosum*. In: S. Woodward, J. Stenlid, R,. Karjalainen and A. Huttermann, Eds. *Heterobasidion annosum*: Biology, Ecology, Impact and Control. CAB International 1988.

Otrosina, W.J., and F.W. Cobb, Jr. 1989. Biology, ecology, and epidemiology of *Heterobasidion annosum*. p. 26-33. In: Otrosina, W.J., and R.F. Scharpf, technical coordinators. 1989. Proceedings of the Symposium on Research and Management of Annosus Root Disease (*Heterobasidion annosum*) in Western North America. April 18- 21, 1989; Monterey, CA. USDA Forest Service, General Technical Report PSW-116. 177 p.

Otrosina, W.J. T.E. Chase and F.W. Cobb. 1992. Allozyme differentiation of intersterility groups of *Heterobasidion annosum* isolated from conifers in the western United States. Phytopathology Vol. 82 No. 5 pp 540-545.

Otrosina, W.J. and M. Garbelotto. (in press). *Heterobasidion occidentale* sp.nov. and *Heterobasidion irregulare* nom. nov.: A disposition of North American *Heterobasidion* biological species. Mycological Research, Elsevior.

Parmeter, J.R., N.J. MacGregor and R.S. Smith. 1918. An evaluation: of *Fomes annosus* in Yosemite National Park. USDA Forest Service. Report No. 78-2. 11 p.

Schmitt, C. L., J.R. Parmeter and J.T. Kliejunas. 2000. Annosus root rot of Western Conifers. Forest Insect and Disease Leaflet No. 172. USDA Forest Service. 9 p.

Smith, R.S., Jr. i993. Root Diseases. p. 136-149. In: Scharpf, R.F., technical coordinator. 1993. Diseases of Pacific Coast Conifers. USDA Forest Service, Agricultural Handbook 521. 199 p.

Smith, R.S. 1984. Root disease caused losses in the commercial forests of the Western United States. USDA Forest Service, Ft. Collins, Co. For. Pest. Manag. Appl. Grp. Rep. 85-5.

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

Smith, R. S. unpbl. Survival of *Fomes annosus* in small stumps of eastside ponderosa pine. Internal document, PSW Forest Research Station (submitted to Phytopathology).

Wood, R.E., M.J. Schuft and D.E. Schultz. 1979. An evaluation of tree mortality in Laguna Mountain Recreation Area, Cleveland National Forest. USDA Forest Service·, R5 Report No. 79-1. 22p.

64 - Pest prevention and Exclusion

64.1 - Firewood Best Management Practices (BMPs) for Reducing the Spread of Invasive Insects and Diseases in Cut Wood

1. Introduction: Invasive insects and diseases are currently threatening numerous hardwood and pine species throughout the country. Introduced bark beetles, w0od borers, and diseases can be transported via cut wood to new areas reducing tree and forest health, increasing tree mortality, and impacting forest and urban habitats. Properly managing cut wood can effectively reduce the risk of introducing these organisms to different regions of the state and country, thereby slowing the spread, damage, and threat to native ecosystems. "Cut wood" shall mean any kindling, firewood, logs, chunkwood, boards, timbers or other wood of any tree species or type cut, split or not split, into a form and size appropriate for use as fuel.
2. Recommendations for BMPs in the National Forests of California: Adhering to the following BMPs can reduce certain insects and diseases from spreading via cut wood within National Forests System lands.
    a. Ensure local firewood is more accessible to forest visitors in sites following tree thinning or fuel treatments. Establish firewood cutting areas where un- infested, well-seasoned (greater than 2 years) firewood is available for collection while following standard operating procedures for fuels and forest· health concerns. When firewood cutting is permitted for an area, taken into consideration the current distribution of invasive insects and diseases threatening California (e.g. limit wood removal in areas where invasive species are present), host tree species, and condition of the wood (time since tree is cut and if bark is present or absent) .
    b. Work with permit holders and forest visitors to minimize the transportation of firewood into sites from long distances (greater than 50 miles) outside National Forest System land boundaries. Direct firewood suppliers and recreationists to the aforementioned forest thinning and fuel reduction areas or local sources of firewood.
    c. Work with concessionaires to only allow commercial loads of firewood onto National Forest System lands from vendors if a bill of sale is provided, firewood is certified un-infested, or the load is issued a phytosanitary certificate by a government official thus verifying the wood is sanitized.
    d. Work with local USDA Forest Service, Forest Health Protection staff in developing specific guidelines to minimize the spread of pests if non-quarantined invasive insects or diseases are established on National Forest System lands or in the county. Federally and state quarantined pests should follow specific guidelines set forth by the Animal Plant Health Inspection Service ·or California Department of Food and Agriculture, respectively.
    e. General BMPs for reducing the risk of transporting invasive insects and diseases in cut wood are as follows[1]:
        (1) Grinding wood to a particle size of less than one (1) inch can successfully eliminate most wood boring insects.
        (2) Chipping wood to a particle size of less than one (1) inch-can effectively reduce the risk of wood boring beetles.
        (3) Heat treatment of infested wood material to an internal wood temperature of 140° F for a minimum of 60 minutes has been shown to eliminate insects and diseases from firewood.
        (4) Removing greater than 95% of the bark from a single tree can kill or reduce certain insects found feeding solely in or under the · bark, such as bark beetles and some wood borers.

[1] References for managing cut wood with insects and disease, the threats of moving cut wood, invasive species education, and links to additional information about preventing the movement of cut wood are listed in the appendix.

(5) Drying Cut wood on site for greater than two (2) years prior to movement can reduce the human-assisted dispersal of most invasive insects. Processing cut wood into firewood-sized pieces is not an acceptable option for reducing the risk of invasive insects.
(6) Do not issue firewood collection permits in areas with known invasive pests and prevent the movement of the impacted tree species.

f. Promote education and awareness about the threats of moving cut wood to forest staff and visitors at trailheads, administration sites, recreation areas, permitted sites, including campgrounds, recreation residences, resorts, organizational camps, etc., and other high-use areas.
(1) Distribute information packets for Forest Service employees and volunteers to maintain a consistent message that includes talking points,

g. Associate education and outreach with forest recreation online, annual correspondence for recreation residences, or phone reservations for permitted areas to bring awareness to the threats of moving firewood and associated BMPs. This can be accomplished by adopting a consistent message that is coordinated with other Federal and State partners.

3. Recommendations for BMPs for National Forest System Lands Visitors: Visitors should be made aware of the pest organisms that can be transported by firewood. Visitors should be educated and encouraged to protect National Forests by doing the following:
   a. Buying firewood from local sources.
   b. Not transporting firewood more than 50 miles from the location where initially cut[2]. Prevention is always the safest practice.
   c. Asking for a bill of sale or permit when buying firewood from local dealers[3]. The bill of sale should list the location where the firewood trees were cut, the date cut, and the tree species. Visitors should buy local firewood and avoid species that may contain invasive species.
   d. When camping, buy local firewood and leave the unused wood on site. "Burn it where you buy it" practice should be followed.
   e. Seasoning cut wood on site for greater than two years. Cut wood seasoned greater than two years poses less of a threat to forest health and can reduce the risk of transporting most invasive insects.
4. Invasive pests associated with moving cut wood in the U.S. and California: The following insects and disease currently represent threats to hardwood and conifer species. Movement of cut wood from the impacted areas should follow federal and state quarantines, if applicable, or incorporate additional management practices to limit the human-assisted dispersal of these non-quarantined organisms.

[2] Local infestations should follow current restrictions (County) or certifications, and National Firewood Task Force Recommendations, March 2010.
[3] California Penal Code 384.5. (a)

Appendix

If any of the links below are not working, try copying the entire link and pasting it into Google Chrome.

Federally quarantined species in the U.S.:

Emerald ash borer, *Agrilus planipennis*

http://www.emeraldashborer.info/
http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ashb/index.shtml
https://www.dontmovefirewood.org/pest_pathogen/emerald-ash-borer-html/
https://www.invasivespeciesinfo.gov/terrestrial/invertebrates/emerald-ash-borer/

Asian Longhorned Beetle, *Anoplophora glabripennis*

https://www.aphis.usda.gov/aphis/ourfocus/planthealth/plant-pest-and-disease-programs/pests-and-diseases/asian-longhorned-beetle/asian-longhorned-beetle
https://www.fs.usda.gov/naspf/publications/asian-longhorned-beetle-and-its-host-trees
http://www.beetlebusters.info/
https://www.dontmovefirewood.org/pest_pathogen/asian-long-horned-beetle-html/
http://www.invasivespeciesinfo.gov/animals/asianbeetle.shtml
http://cisr.ucr.edu/asian_beetle.html

Federally quarantined species in California:

Sudden oak death, *Phytophthora ramorum*

http://www.suddenoakdeath.org/
https://www.dontmovefirewood.org/pest_pathogen/sudden-oak-death-syndrome-html/
http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn74151.html
http://www.invasivespeciesinfo.gov/microbes/suddenoak.shtml
https://cisr.ucr.edu/invasive-species/sudden-oak-death

Non-quarantined invasive species in the U.S.:

European woodwasp, *Sirex noctilio*

https://www.invasivespeciesinfo.gov/terrestrial/invertebrates/sirex-woodwasp

Redbay Ambrosia beetle, *Xyleborus glabratus*, and Laurel Wilt disease, *Raffaelea lauricola*, complex

https://www.fs.fed.us/research/invasive-species/plant-pathogens/laurel-wilt.php
https://www.invasivespeciesinfo.gov/terrestrial/pathogens-and-diseases/laurel-wilt
https://www.dontmovefirewood.org/pest_pathogen/laurel-wilt-html/
https://cisr.ucr.edu/invasive-species/redbay-ambrosia-beetle-and-laurel-wilt

Non-quarantined invasive species in California:

Goldspotted oak borer, *Agrilus auroguttatus*

https://ucanr.edu/sites/gsobinfo/
https://www.dontmovefirewood.org/pest_pathogen/goldspotted-oak-borer-html/
https://cisr.ucr.edu/invasive-species/goldspotted-oak-borer

Pitch canker disease, *Fusarium circinatum*
https://www.dontmovefirewood.org/pest_pathogen/pine-pitch-canker-html/
https://ufei.calpoly.edu/pitch_canker/index.lasso

Redhaired pine bark beetle, *Hylurgus ligniperda*
https://www.cabi.org/isc/datasheet/27364
https://www.fs.usda.gov/naspf/sites/default/files/publications/red_haired_bark_beetle.pdf
https://www.dontmovefirewood.org/pest_pathogen/red-haired-pine-bark-beetle-html/
https://www.fs.fed.us/research/invasive-species/insects/bark-beetle.php

Mediterranean pine engraver, *Orthotomicus erosus*
https://www.dontmovefirewood.org/pest_pathogen/mediterranean-pine-engraver-beetle-html/
https://www.nrs.fs.fed.us/disturbance/invasive_species/pine_engraver/

Thousand canker disease, *Geosmithia morbida*
http://thousandcankers.com/
https://www.dontmovefirewood.org/pest_pathogen/thousand-canker-disease-html/
https://www.invasivespeciesinfo.gov/terrestrial/pathogens-and-diseases/thousand-cankers-black-walnut-disease
https://www.aphis.usda.gov/aphis/ourfocus/planthealth/plant-pest-and-disease-programs/pests-and-diseases/thousand-cankers-disease/thousand-cankers-disease

Polyphagus shot hole borer, *Euwallacea* sp.
https://cisr.ucr.edu/invasive-species/polyphagous-shot-hole-borer

Additional information about the threats associated with moving cut wood:

USDA Forest Service: https://www.nrs.fs.fed.us/disturbance/invasive_species/firewood_survey/
CA Firewood Task Force: http://www.firewood.ca.gov/
Continental Dialogue: https://www.dontmovefirewood.org/
APHIS: https://www.aphis.usda.gov/aphis/ourfocus/planthealth/import-information/firewood

REFERENCES

Appel, D.N., R.S. Cameron, A.D. Wilson, and J.D. Johnson. 2008. How to identify and manage oak wilt in Texas. Texas Forest Service. How-To SR-1.

Barak, A.V., Y. Wang, G. Zhan, Y. Wu, L. Xu, and Q. Huang. 2006. Sulfuryl fluoride as a quarantine treatment for *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in regulated wood packing material. J. Econ. Entomol. 99: 1628-1635.

Barak, A.V.,W.D.- Yang, D.J. Yu, Y. Jiao, L. Kang, Z.L. Chen, X.Y. Ling, and G.P. Zhan. 2009. Methyl bromide as a quarantine treatment for *Chlorophorus annularis* F. (bamboo borer) (Coleoptera: Cerambycidae) in raw bamboo poles. J. Econ. Entomol. 102: 913-920.

Borchert, D., L. Newton, T. Culliney, H. Hartzog, R. Ahem, L. Garrett. 2010. Risk Assessment of the Movement within the United States. Ed. Jackson, A. USDA Animal Plant Health Inspection Service.

Buff am, P.E., and D.D. Lucht. 1968. Use of polyethylene sheeting for control of *Ips* spp. in logging debris. J. Econ. Entomol. 61: 1465-1466.

Canadian Food Inspection Agency. 2006. Canadian heat-treated wood products certification program (CHTWPCP). (https://www.inspection.gc.ca/plant-health/forestry/exports/ht-program/eng/1319462565070/1319462677967).

Childester, M.S. 1939. Further studies on temperatures necessary to kill fungi in wood. Proc. Am. Wood Preservers Assoc. 35: 319-324.

Dunbar, D.M., and G.R. Stephens. 1974. Two-lined chestnut borer: effects of storage conditions, processing, and insecticides on its survival in oak logs. J Econ. Entomol. 67: 427-429.

Dwinell, D.L. 1990. Heat-treating and drying southern pine lumber infested with the pinewood nematode. For. Prod. J. 40: 53-56.

[FAO] International Standards for Phytosanitary Measures. 2002. Guidelines for regulating wood packaging material in international trade. Publication No. 15. Food and Agriculture Organization, Rome, Italy.

Goebel, P.C., M.S. Bumgardner, D.A. Herms, A. Sabula. 2010. Failure to sanitize ash firewood infested with emerald ash bore in a small dry kiln using ISPM-15 standards. J. Econ. Entomol. 103: 597-602.

French, J.R.J., and RS. Johnstone. 1968. Heat sterilization of block-stacked timber in wood-destroying insect control. J. Inst. Wood Sci. 20: 42-46.

Haack, RA., and D.M. Benjamin. 1980. Influence of time of summer felling of infested oak trees on larval development and adult emergence of the two-lined chestnut borer, *Agrilus bilineatus*. Univ. Wisc. For. Res. Notes No. 236.

Jacobi, W., C. Cleaver, B. Goodrich, and J. Hardin. 2009. Firewood as a potential pathway for exotics in the Southern Rocky Mountains. 5th meeting of the Continental Dialogue on Non-Native Forest Insects and Diseases, October 27-28, 2009, San Francisco, CA.

Jacobi, W.R., B.A. Goodrich, and C.M. Cleaver. 2011. Firewood Transport by National and State Park Campers: A Risk for Native or Exotic Tree Pest Movement, Arboriculture & Urban Forestry 37(3): 126-138.

McCullough, D.G., T.M. Poland, D. Cappaert, E.L. Clark, I. Fraser, V. Mastro, S. Smith, and C. Pell. 2007. Effects of chipping, grinding, and heat on survival of emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), in chips. J. Econ. Entomol 100: 1304-1315.

Miric, M., and H. Willeitner. 1984. Lethal temperature for some wood-destroying fungi with respect to eradication by heat treatment. Doc. No. IGR/WP/1229. Inter. Res. Group Wood Press, Stockholm, Sweden.

Mizobuti, M., I. Matsuoka, Y. Soma, H; Kishino, S. Yabuta, M. Imamura, T. Mizuno, Y. Hirose, and F. Kawakami. 1996. Susceptibility of forest insect pests to sulfuryl fluoride. 2. Ambrosia beetles. Res. Bull. Plant Prot. Jpn. 32: 77-82.

Myers, S.W., I. Fraser, and V. Mastro. 2009. Evaluation of heat treatment schedules for emerald ash borer (Coleoptera: Buprestidae). J Econ. Entomol. 102: 2048-2055. •

Neven, L.G. 1998. Effects of heating rate on the mortality of fifth-instar codling moth. J. Econ. Entomol. 91: 297-301.

Newbill, M.A., and J.J. Morrell. 1991. Effects of elevated temperatures on the survival of *Basidiomycetes* that colonize untreated Douglas-fir logs. For. Prod. J. 41: 31-33.

Nzokou, P., S. Tourtellot, and D.P. Kamden. 2008. Kiln and microwave heat treatment of logs infested by the emerald ash borer (*Agrilus planipennis* Fairmaire) (Coleoptera: Buprestidae). For. Prod. J. 58: 68-72.

Petrice, T.R. and R.A. Haack. 2006. Effects of cutting date, outdoor storage conditions, and splitting on survival of *Agrilus planipennis* (Coleoptera: Buprestidae) in firewood logs. J. Econ. Entomol. 99: 790-796.

Poland, T.M., T.M. Kuhn, C. Zhangjing, A. Diss-Torrance, and E. L. Clark. 2008. Evaluation of firewood bagging and vacuum treatment for regulatory control of emerald ash borer. pp. 24-26. In: Emerald Ash Borer Research and Development Review Meeting. Compilers: V. Mastro, D. Lance, R. Reardon, and G. Parra. October 23-24, 2007; Pittsburgh, PA. FHTET 2008-07. Morgantown, WV: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team p. 124.

Smith, R.S. [ed.]. 1991. The use of heat treatment in the eradication of the pinewood nematode and its vectors in softwood lumber. Report to the Task Force on Pasteurization of Softwood Lumber, Forintek Canada Corporation, Vancouver, BC, Canada.

Snyder, T.E. and R.A. St. George. 1924. Determination of temperature fatal to the powder post beetle, *Lyctus planicollis* LeConte, steaming infested ash and oak lumber in a kiln. J. Agric. Res. 28: 1033-1038.

Soma, Y., S. Yabuta, M. Mizoguti, H. Kishino, I. Matsuoka, M. Goto, T. Akagawa, T. Ikeda, and F. Kawakami. 1996. Susceptibility of forest insect pests to sulfuryl fluoride. 1. Wood borers and bark beetles. Res. Bull. Plant Prot. Jpn. 32: 69-76.

Soma, Y., M. Mizobuchi, T. Oogita, T. Misumi, H. Kishono, T. Akagawa, and F. Kawakami. 1997. Susceptibility of forest insect pests to sulfuryl fluoride. 3. Susceptibility to sulfuryl fluoride at 25_C. Res. Bull. Plant Prot. Jpn. 33: 25-30.

Soma, Y., H. Naito, T. Misumi, M. Mizobuchi, Y. Tsuchiya, I. Matsuoka, and F. Kawakami. 2001. Effects of some fumigants on pine wood nematode, *Bursaphelenchus xylophilus*, infecting wooden packages. Res. Bull. Plant Prot. Jpn. 37: 19-26.

Tomminen, J., and M. Nuorteva. 1992. Pinewood nematode, *Bursaphelenchus xylophilus* in commercial sapwood and its control by kiln-heating. Scand. J. For. Res. 7: 113-120.

Wang, B., V.C. Mastro, and W.H. McLane. 2000. Impacts of chipping on surrogates for the longhomed beetle *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in logs. J. Econ. Entomol. 93: 1832-1836.

Yu, D., AV. Barak, Y. Jiao, Z. Chen, G. Zhang, Z. Chen, L. Kang, and W. Yang. 2010. Sulfuryl fluoride as a quarantine treatment for *Chlorophorus annularis* (Coleoptera: Cerambycidae) in Chinese Bamboo Poles. J. Econ. Entomol. 103: 277-283.