Uprooting and Trenching to Control Annosus Root Disease in a Developed Recreation Site: 12-Year Results

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ABSTRACT: *Six annosus (*Heterobasidion annosum*) root disease centers in a proposed campground on the north shore of Big Bear Lake in southern California were treated in 1989. Trees, stumps, and roots were removed in six disease centers, and in two cases, soil trenching was used to stop the progress of the disease. A total of 154 trees and 26 stumps were removed; 300 linear feet of trenching was done around two disease centers. Of 101 trees sampled, 47% were infected with* H. annosum. *Sixteen percent of infected trees exhibited no visible crown symptoms. The pathogen was isolated from 50% of roots that showed resinosis and 14% of roots not exhibiting resinosis. Only the P biological species was present on living, infected Jeffrey pine and juniper roots. Twelve years after treatment, all six sites appear to be disease free with no aboveground symptoms of root infection. Tree mortality is continuing on untreated disease centers in this recreation area. West. J. Appl. For. 20(3):154–159.*

Key Words: Root disease, *Heterobasidion annosum.*

Annosus root disease (ARD), caused by *Heterobasidion annosum,* is widespread and damaging in southern California recreation sites (Bega and Smith 1966). In addition to creating hazardous trees, the disease results in unwanted openings and depletion of desirable vegetative cover. ARD is a major limiting factor in establishing and maintaining conifers in many southern California recreation sites and, as a result, the recreational values of the sites are reduced. A 1978 survey (Wood 1978) in the proposed Big Bear Lake North Shore Recreation Area, San Bernardino National Forest, identified 43 annosus root disease centers. Annosus root disease similarly impacts other campgrounds in southern California. For example, about 40% of the 12-ac Barton Flats Campground, also on the San Bernardino National Forest, is infested with ARD and about six to eight pines are killed each year on this site (Allison, personal observations). Natural regeneration of conifers is nonexistent in the disease centers, and young trees on the margins continue to develop symptoms and die. Heavy impacts are also observed in recreation sites on the Cleveland and Los Padres National Forests. The ARD problem must be minimized in heavily used recreation sites if a safe and satisfactory recreational experience is to be provided.

Heterobasidion annosum attacks a wide range of woody plants. Two host-specific biological species have been identified in California. The P biological species infects pines, incense-cedar, western juniper, and certain hardwood species. True firs, Douglas-fir, spruce, western redcedar, giant sequoia, and western hemlock are attacked by the S biological species.

Airborne spores produced in *H. annosum* basidiocarps land and germinate primarily on freshly-cut stump surfaces. The fungi then colonizes the stump wood and grows into the root system. Spread from the infected stump roots is via root contacts and root grafts with adjacent, susceptible conifers. This tree-to-tree progression results in an enlarging circle, or infection center, occupied by dead or dying trees (Otrosina and Scharpf 1989). Infection centers may continue to enlarge until they reach barriers to expansion, such as large open areas devoid of susceptible root systems or areas dominated by nonsusceptible tree species.

Heterobasidion annosum may remain alive in infected roots or stumps for many years (Smith 1983). Susceptible conifers established within infection centers often die shortly after their roots contact roots of previously diseased trees. Because all conifers are susceptible to annosus root disease, attempts to revegetate ARD centers in recreation sites are now limited to conifers resistant to the existing

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biological species (P or S) of *H. annosum* on the site. Hardwoods or nonsusceptible brush species are also alternatives, but these are difficult to establish in the drier regions of California.

Under climatic conditions occurring in much of California, *H. annosum*-infested woody material may take up to 50 years to break down (Smith 1983). Within this time period, infection is possible in newly established susceptible conifer species, whether they are naturally or artificially regenerated. One direct control method for ARD is to remove infected stumps and roots. Because the pathogen is transmitted locally via root contacts with infected woody material, removal of such inoculum from the soil should allow for successful and timely establishment of susceptible conifers in these previously active infection centers. This theory forms the basis for stump-root extraction or "stumping" of sites prior to replanting with susceptible species. In other situations, stopping ARD progression by creating a buffer zone around an infection center may be feasible. To accomplish this, inoculum removal, removal of conifers at the margin of the infection centers, and trenching to break root contacts and to create a buffer strip between healthy and diseased trees are carried out. An attempt to halt spread of ARD by trenching to a depth of 6 to 7 ft, followed by soil fumigation, was unsuccessful in Eddy Arboretum, Institute of Forest Genetics, Placerville, California (Srago 1976), presumably because infection of roots beyond the trench had already occurred.

On the other hand, efficacy of removing infected roots during stand harvest to restore timber productivity has been demonstrated in commercial timber stands with *Phellinus weirii* and *Armillaria ostoyae* root disease. (Arnold 1981, Bloomberg and Reynolds 1988, Morrison et al. 1988, Thies 1984, 1987, Wallis 1976). Similar to *H. annosum*, these fungi are spread via root-to-root contacts. Bloomberg and Reynolds (1988) compared equipment for removing residual woody roots. They found that a large backhoe (180 horsepower) was most effective, and concluded that levels of inoculum were reduced below those likely to result in sufficient root contacts to produce infection in the newly regenerated stand. Pushing over infected trees, followed by removal of roots by machine and by hand, reduced mortality caused by *Armillaria ostoyae* in a ponderosa pine forest (Roth et al. 2000). Removal of red pine (*P. resinosa*) stumps infected with *H. annosum* has eradicated the disease on relatively small, infested sites in a Quebec plantation (Laflamme and Blais 1997).

The objective of this study was to determine the feasibility of establishing and maintaining vegetative cover in developed recreation sites by uprooting *H. annosum*-infected stumps and trees, and by trenching, to directly control annosus root disease.

Methods

Study Location and History

Big Bear Lake in southern California is a 3,000-ac reservoir created in 1884. Because public access to the lake was limited but desired, the Forest Service purchased 420 ac along the north shore to provide recreation opportunities. Vegetation in the area consists of Jeffrey pine (*Pinus jeffreyi*) in the overstory, and Jeffrey pine, western juniper (*Juniperus occidentalis*), and single leaf pinyon (*Pinus monophylla*) in the understory. Curl leaf mountain mahogany (*Cercocarpus ledifolius*) is the only native hardwood in the immediate area.

In 1978, the San Bernardino National Forest proposed to develop the north shore area of the lake for recreation use by about 1,750 people per day. Maintaining the natural forest appearance was also a key objective. Proposed development included a campground (now named Serrano), amphitheater, day use area, and trails. Although no major logging activity historically had taken place within the area, numerous stumps and lack of snags throughout the site indicated that salvage of dead trees had been a continuous management practice for many years, probably dating back to the mid-1800s.

Because a stand examination conducted by the forest silviculturist in 1977 suggested that ARD was common in the area and causing damage, the Forest requested Forest Health Protection (FHP) to provide recommendations on how to maintain vegetative cover in and around the ARD centers. Forest Health Protection conducted a detailed survey in 1978 of sites proposed for development (Wood 1978). A total of 46 root disease centers, 43 caused by *H. annosum*, two caused by *Armillaria* sp., and one caused by *Leptographium wageneri*, were located over about 800 ac, mapped, referenced to control points used in surveying the campground, and marked on aerial photographs. Recommendations made by FHP for disease control included removal of trees exhibiting symptoms of root disease and removal of those that would probably die in the next 5 years, based on proximity to symptomatic trees. A total of 125 trees were banded by blue and white flagging and tagged at the base with numbered metal tags facing into the infection centers. It was suggested that removal of the trees could be delayed until just before or during construction to better determine the rate of decline due to *H. annosum*.

Final plans for development of the area, by then known as the Big Bear Lake North Shore Recreation Area, were completed in 1988.

Site Descriptions

In May of 1988 the proposed development was re-surveyed by FHP and Forest personnel, and most of the root disease centers identified in 1978 were re-located. Six active annosus root disease centers appeared suitable for our study to determine the feasibility of direct ARD control (Figure 1). The six sites were chosen because they had relatively discrete, active infection centers with distinct margins between dying trees and healthy appearing trees in the surrounding forest. Site one was a small, active center, advancing at its southern margin into an adjacent, healthy Jeffrey pine stand. Sites two and five were active disease centers advancing east, south, and west into adjacent Jeffrey pine stands. Site three was an approximately 0.75 ac, very open, disease center actively advancing south into a stand of 10 to

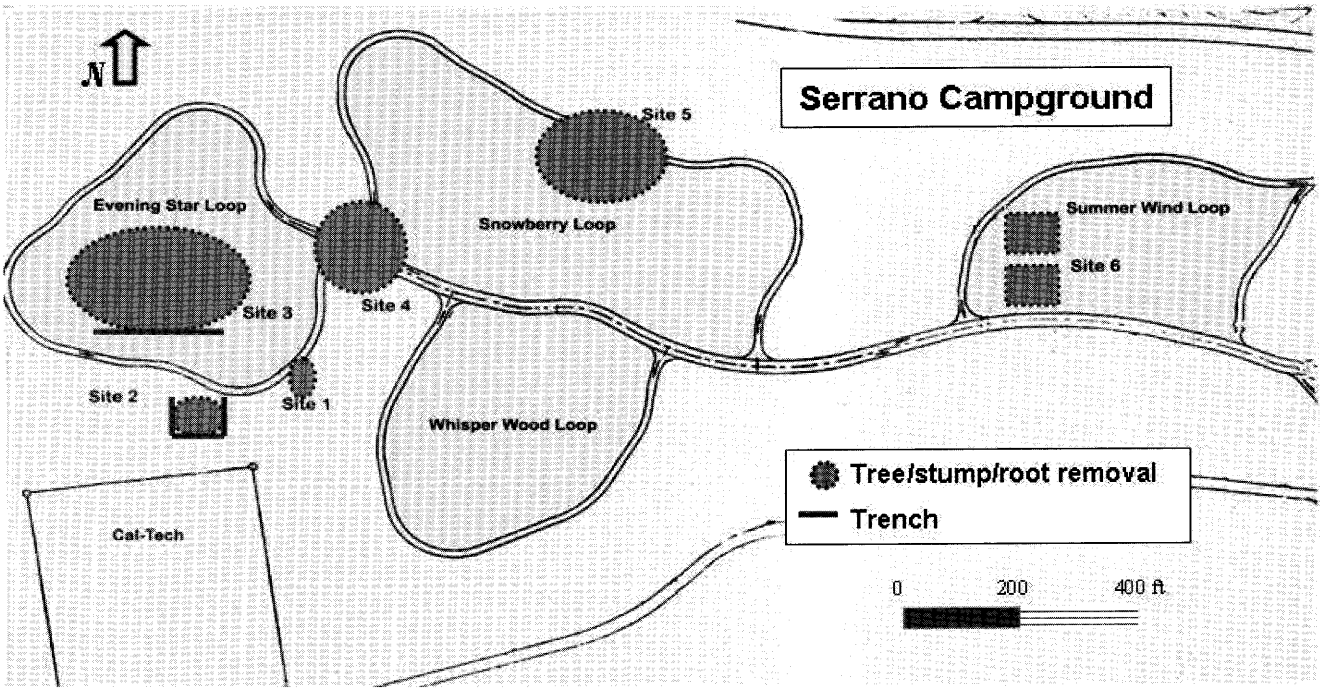

Figure 1. Location of annosus root disease centers at Serrano Campground, San Bernardino National Forest.

36 in. diameter at breast height (dbh) Jeffrey pine. Site four was an active disease center with numerous dead and dying western junipers present. Site six consisted of two root disease centers, one treated and one not, to demonstrate any differences in survival following planting of susceptible trees in the untreated center and in the center with inoculum removed.

Treatments

Treatment of the sites began in July 1989. These included removal of living conifers and their root systems, and removal of conifer stumps and roots at all six sites; and trenching at margins of active disease at two sites (Figure 1). Inoculum removal was done in an attempt to cleanse the site while trenching was done to prevent root-to-root-spread of the pathogen into adjacent uninfested stands.

Tree, Stump, and Root Removal.—All conifers, stumps, and visible roots were removed with a backhoe within selected ARD centers (sites one through five). Site number six was split into two portions, one portion with a disease center that was treated by stump and woody inoculum removal, and one portion with a disease center that was not treated. The "centers" at the six sites were defined as discrete areas with symptomatic conifers. At sites one, two, four, five and six, only symptomatic living trees were removed at apparent margins of the centers. No attempt was made to create a buffer by removal of trees with no aboveground symptoms at the margins. At site number three, roots of trees at the southern margin of the disease center were examined and removed. If decay or resin soaking indicative of *H. annosum* infection were found, an additional tree into the healthy stand was removed. The three pieces of equipment used in this operation were a rubber-tired model 755 backhoe, a model 977 loader, and a dump truck.

Smaller-diameter (about 4 in. or less dbh) Jeffrey pine and juniper were grasped by the bucket of the loader, lifted out, and removed (Figure 2). Trees 4 to 12 in. dbh were pushed over by the loader bucket or, alternatively, the bucket was lowered and the tree lifted out at the groundline and pushed over.

Two methods to remove trees larger than about 12 in. dbh were tested. Stems were either pushed over with the raised bucket (Figure 3), allowing the weight of the tree to dislodge the roots from the soil; or the stems were cut and the remaining stump and roots then lifted out. Pushing over

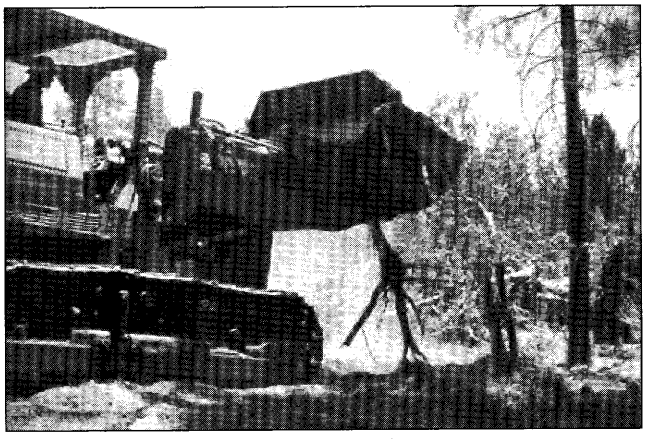

Figure 2. Smaller diameter Jeffrey pines were pulled out with the bucket of the loader.

Figure 3. Large diameter trees were pushed over with the bucket of the loader.

the larger trees was judged more successful in that it removed more roots, and it became the standard procedure in this case.

Extracted stumps and larger roots were put in a dump truck and removed from the site. Records were kept of numbers and sizes of material removed from each site to document costs. The backhoe then removed buckets of soil around each stump area, and set the buckets of soils to the side, where visible pieces or roots were removed by hand. The holes were then backfilled with the screened soil, and the area was leveled with the loader.

Trenching.—At sites two and three, live infected trees and adjacent conifers were cut and pushed over to create a buffer between the disease center and the healthy stand. A 5-ft-deep by approximately 3-ft-wide trench was dug with the backhoe to break root contacts between diseased and healthy roots (Figure 4). The trench was dug at least one row of trees, approximately 10–20 ft beyond trees where root infection was found. In the trenched areas, roots of selected trees were sampled to determine the degree of infection in relation to aboveground symptoms. Crowns were mapped and rated for symptoms, and roots examined and sampled. The trenches were filled back in using the same methods of soil screening as used for stump removal.

Figure 4. Trenching to a 5-foot depth broke root contact between infected and healthy roots.

Treatment Costs

Because the procedures tested and the costs involved were to be used to demonstrate efficacy, documentation of the project included maintenance of records of cost involved in carrying out the project.

Evaluation of Treatment Effectiveness

Efficacy of the treatments was evaluated by planting tree and brush species in 1990, the spring following treatment, at several of the sites. Planted trees were monitored yearly for aboveground symptoms of *H. annosum* infection. Jeffrey pines and valley oak (*Quercus lobata*) were transplanted to the nontreated center (10 Jeffrey pine and 10 oaks) and to the treated center (10 Jeffrey pine and 10 oaks) at site number six. The transplanted species, removed with a tree spade, were generally 1 to 3 in. in diameter and 5 to 8 ft in height.

Jeffrey pine and additional species, including juniper, valley oak, and curl leaf mountain mahogany, were also transplanted into the openings created at other sites (site number two: two Jeffrey pine, three oaks; site number three: eight Jeffrey pine, seven oaks, two curl leaf mountain mahogany; site number five: five Jeffrey pine, five oaks, five curl leaf mountain mahogany) to re-establish vegetative cover and to help provide a barrier of nonsusceptible roots to pathogen spread. The pines were examined periodically for aboveground symptoms of *H. annosum* infection. The transplanted material, which varied is size from 4 to 8 ft in height, were removed with a tree spade from uninfested areas on the Forest.

A drip irrigation system necessary for successful establishment of the planted material in the Mediterranean climate of the area was installed at the six sites. The objective was to water the planted vegetation for 2 years after planting. In practice, the system was not maintained and became nonfunctional after the first year.

Results

Sites Treated

In 2.5 days, six pathologists, three equipment operators, and three individuals from the Forest removed 154 trees, 26 stumps, and dug 300 linear ft of trench. Tree and stump diameters ranged from less than 1 in. dbh to over 40 in. dbh for several junipers. The majority of the trees were in the 10- to 24-in. dbh range.

Relationship Between Aboveground Symptoms and Root Infection

Roots of 101 uprooted Jeffrey pine and juniper at sites one through four were collected and taken to the laboratory for isolation. As expected, the majority (58%) of the trees exhibiting even mild crown symptoms were infected. However, *H. annosum* was also recovered from a significant number (16%) of trees exhibiting no aboveground symptoms. This agrees with literature and our observations suggesting that aboveground symptoms of root infection become apparent only when more than 50 to 66% of a root

system is nonfunctional (Grieg 1998). All *H. annosum* isolates we obtained in this study were the P biological species as determined by isozyme analyses (Otrosina et al. 1992).

Presence of resinosis in roots of pine may be an indicator of possible infection, although 50% of the resinous roots sampled did not yield *H. annosum*. On the other hand, *H. annosum* was isolated from only 14% of roots without resinosis. Thus, observing resinosis in roots should raise suspicions regarding *H. annosum* infection status in pine. Infected junipers did not exhibit significant root resinosis.

Treatment Cost

The total treatment cost for the 2 years was approximately $10,000. The cost for the 1989 sanitation work was $6,200 (backhoe for old stump removal, $1,000; D6 for live tree and root removal, $3,000; loader/truck for stump/root removal from site, $1,700; backhoe for trenching, $200; and gopher control, $300). These costs do not include the salary of nine individuals for 2.5 days. Follow-up treatment cost in 1990 was $3,800 (tree spade work and establishment of irrigation system, $3,500; gopher control, $300).

Obviously, actual costs would be higher now. However, the relative costs are informative and useful for their comparative utility. The cost of recapturing an infested site (removal and disposal of infested material, planting and irrigation, and gopher control) is considerably higher than preventing spread into an uninfested site by trenching.

Posttreatment Evaluation

The treated areas and surrounding stand, now known as Serrano Campground, were re-visited in 1995, 6 years after treatment. Some roads and campsite spurs drawn on the original site plans had been re-aligned to take advantage of *H. annosum* centers mapped in 1989. Roads were re-aligned to be over rather than adjacent to disease centers, and some campsite spurs were moved to coincide with areas of soil disruption from the treatments. This avoided problems with maintaining cover to provide vegetative screening between campsites.

Treatments, both tree and stump removal and trenching, appeared to have stopped spread of the disease into adjacent healthy stands. No aboveground symptoms of *H. annosum* infection were observed in or adjacent to treated sites. In contrast, the disease was active in untreated areas of the campground. One suspected *H. annosum*-infected Jeffrey pine was observed at the east end of the 150-ft trench at site three. However, the pathogen was not isolated from sampled roots. Sapling-size Jeffrey pines planted in the treated areas had no aboveground symptoms of root infection. The trees appeared under stress (with little or no terminal growth), probably due to deterioration of the drip irrigation system, the presence of gophers, and grass growth. Oaks planted in the treated areas where also under stress and frost damage was evident on many of the trees. Dwarf mistletoe infection was noted on two of the transplanted Jeffrey pine trees; the parasite apparently had been brought in on the spaded trees.

The 20 Jeffrey pines planted in the treated (10) and nontreated (10) annosus centers at site six appeared healthy, with no differences observed between the two treatments.

The campground was visited again in Apr. 1999, 10 years after treatment. No aboveground symptoms of *H. annosum* infection were observed in the treated sites or in adjacent stands. No sampling or culturing work was done. Active ARD centers (dead and dying junipers adjacent to juniper stumps) were observed in untreated sites.

The Jeffrey pines, oaks, and brush species planted 9 to 10 years previously were mostly well-established, although evidence of stress in some trees remained. Two of the six Jeffrey pines planted in the untreated disease center at site six were missing. The suspected *H. annosum*-infected Jeffrey pine near the trench at site number three was dead.

Observations made in May 2001 were similar to those made in 1999. Hosts in the treated sites and in adjacent stands had no aboveground symptoms of ARD infection. Other areas of the campground did have active ARD.

Discussion

Results 12 years after treatment indicate that site sanitation by removal of *H. annosum*-infected trees and roots at the time of campground development may have significantly reduced conifer mortality caused by the root pathogen. The result we obtained in this recreation site agrees with results from use of similar inoculum removal or inoculum limiting methods in a plantation (LaFlamme and Blais 1997) and in timber stands (Morrison et al. 1988, Roth et al. 2000). A recent publication (Sturrock 2000) summarizes inoculum removal trials that have been conducted in Oregon, Washington, and British Columbia on sites infested with *P. weirii* or *A. ostoyae*. In all cases, less mortality occurred on stumped or push-felled plots than on nontreated plots. Our results suggest that the procedure also may be effective with *H. annosum*. Because the treatments at Serrano were done during initial phases of campground development, proposed roads and spurs could be re-aligned to accommodate changes in affected areas due to the treatments. Consequently, the site disturbance was less disruptive than if treatments had been carried out in an already developed campground.

Trenching appears to have eliminated tree-to-tree spread of the root disease into adjacent healthy stands. Examination and sampling of roots during treatment was necessary to determine the extent of *H. annosum* in root systems. It was necessary to remove trees with no aboveground symptoms, but with decayed or resinous roots. Removal of very attractive, desirable trees during treatment was a difficult decision to make, but was probably responsible for the success of the trenching. Previous attempts at trenching to break root contact (Srago 1976) may have been unsuccessful because the pathogen had already infected roots beyond the buffer and trench.

We believe the cost of treatment in this campground was not prohibitive. When considering the infrastructure in an already established campground, the cost of removal of hazard trees resulting from *H. annosum*-caused mortality

over a 10-year period would probably far exceed the prophylactic treatment cost incurred prior to or during campground establishment.

Posttreatment planting of conifers and hardwoods probably would have been more successful with better watering regimes, maintenance of irrigation tubing, and gopher control. Follow-up maintenance of the planted vegetation on this relatively harsh, dry site would have resulted in their more rapid establishment.

The means used to achieve the original objective (to establish and maintain vegetative cover in a developed recreation site by direct control of *H. annosum)* was judged successful, at least for 12 years after treatment. The procedure should be tried at additional planned recreation sites to minimize root disease impacts, and therefore improve the recreational experience.

In many southern California recreation sites, incidence of *H. annosum* is high and the option to plant resistant species is limited to hardwood or brush species. In those situations, direct control via inoculum removal may be a viable alternative to the esthetically less pleasing hardwood or brush vegetation. We recommend during the planning stages for a recreation site, a standard procedure should be to first survey the area for root disease, determine its distribution and potential impacts, and, if deemed necessary, consider all root disease management strategies, including inoculum removal.

Although such direct control appears feasible in some situations, prevention remains the preferred and least costly method of ARD management in recreation areas. Current Forest Service Manual direction requires treatment of all freshly-cut conifer stumps in developed recreation sites in California national forests with Sporax, the currently registered borax compound. The Manual direction should be followed to minimize impacts of *H. annosum* in areas with high-value trees.

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