Chapter 10
Management Techniques and Challenges

Authors: Donald J. Goheen, Frank Betlejewski and Peter A. Angwin

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Introduction

This chapter is a discussion of possible treatment alternatives that can be used alone or in combination. In general, land managers seek to maintain Port-Orford-cedar as a part of the forest ecosystem and reduce the occurrence of *Phytophthora lateralis*. The determination of appropriate management regimes is the choice of the local manager, dependant on site conditions and applicable land use objectives.

In the first three decades after the introduction of *P. lateralis*, few, if any, attempts were made to manage Port-Orford-cedar root disease. The striking virulence of the exotic pathogen and the speed with which it spread along roads and streams as well as the obvious tie between spread, and then-practiced timber harvesting techniques, led to statements such as “there appears to be no hope of raising another crop of Port-Orford-cedar under existing conditions of disease and land use” and production of Port-Orford-cedar “... will likely decline and ultimately drop to nearly nothing as the remaining merchantable trees die or are harvested” (Roth et al. 1972). Many felt that with the pathogen established, active management of Port-Orford-cedar, as a timber species, was no longer possible. Emphasis was placed on extensive salvage of large disease-killed cedars.

Management for Port-Orford-cedar root disease has changed dramatically in the past 30 years. Many forest managers on federal lands administered by the Forest Service and the Bureau of Land Management are now involved in an integrated program to minimize detrimental impacts of the root disease. The difficulties, expenses, and inconveniences associated with managing Port-Orford-cedar are carefully weighed against the need and potential for limiting the spread of the disease.

While *P. lateralis* has caused negative impacts on Port-Orford-cedar populations, the severity varies. In spite of concerns early in the epidemic, the natural range of Port-Orford-cedar has not diminished because of the root disease and the species has not been extirpated from any major area where it has historically been located (Kliejunas 1994). Management techniques discussed in this chapter have been shown to be effective in lessening the occurrence of *P. lateralis* and maintaining Port-Orford-cedar population viability.

General Management Techniques

Operational Planning and Scheduling

Planning access routes and timing projects to minimize the likelihood of *P. lateralis* spread have been routinely suggested as Port-Orford-cedar root disease management techniques and are widely practiced (Erwin and Ribeiro 1996, Goheen et.al. 1997, Harvey et al. 1985, Kliejunas 1994, Roth et al. 1987, Scharpf 1993, Thies and Goheen in press, USDA 1983, Zobel et al. 1985).

Separating forest operations in diseased stands from those in disease-free locations, both in space and time, is a common technique that can be applied to minimize the likelihood of *P. lateralis* spread.

When the local land manager chooses this technique, forest management projects in stands with Port-Orford-cedar, especially in uninfested areas, are typically performed when conditions are unfavorable for pathogen survival and spread. The following practices may be implemented:

- Projects are preferentially scheduled to be completed in the warm, dry months and are discontinued when wet conditions develop, even during the stated operating season.
- Repeated entries into vulnerable microsites are avoided, and work is scheduled to proceed sequentially, from uninfested to infested sites.
- Equipment is not allowed to move from an infested area into an uninfested one.
- Access to project areas is generally planned along routes with the least occurrence of infested sites.

There is abundant evidence that spread of *P. lateralis* is associated with timber harvesting operations that have not addressed timing and access of harvest operations. (Roth et al. 1972, Trione 1959). Where timber-harvesting operations are conducted in stands with Port-Orford-cedar or where streams intersect stands with Port-Orford-cedar below harvest units, systems that minimize the amount of soil movement, especially across slope movement, help minimize the spread of *P. lateralis*.

Use of cable systems or helicopter logging systems lowers the risk of spread compared to tractor-logging systems. Where possible, root disease prevention and management activities can be coordinated with adjacent landowners.

Some forest management projects are limited to wetter periods of the year. Examples include tree planting, prescribed burning, and surveys for certain survey and manage species. Managers may consider precautions such as washing vehicles and other equipment, avoiding routes that pass through infested areas, and walking to project sites rather than driving in such cases.

Integrating Disease Treatments with Road Design, Engineering, and Maintenance

Minimizing the risk of *P. lateralis* spread is an important consideration in designing and building new roads and in maintaining or improving existing roads in areas with Port-Orford-cedar.

For new construction, routing decisions could be made with the knowledge of where Port-Orford-cedar concentrations occur. The risk of the spread of *P. lateralis* can be minimized when new roads or spurs are located below known concentrations of Port-Orford-cedar, or on the opposite sides of ridges.

In new road construction, culverts and waterbars are designed to quickly direct water into existing well-defined water channels away from areas where Port-Orford-cedars exist. Roads may be insloped, and, in some cases, site-specific berms may be used on the outside edges of roads to prevent downslope flow of water. Reshaping of existing roads is sometimes done to create a convex profile.

Risks may further be reduced during road building and maintenance when:

- Road building and maintenance is restricted as much as possible to the dry season and cleaned equipment is used.
- Movement of soil and debris from one place to another during construction or maintenance is minimized.
- Side-casting material into drainage ditches, streams, or over road berms during maintenance along road segments with infected trees is avoided.
- Clean rock (treated rock or rock from disease-free quarries) is selected over river rock.
- Clean rock or pavement is added to existing roads to raise those sections of roadbeds that pass through infested sites.
- Surfacing materials are applied to natural surface roads in areas with *P. lateralis* to reduce the likelihood of vehicle tires coming into contact with infested soil (fig. 10.1).
- Stream crossings on new roads are designed to keep vehicles out of contact with water, and primitive roads that cannot be closed are upgraded so that fords and puddles are eliminated.
- Care is taken in moving soil and other material when end-hauling, repairing flood damage, or removing slides, especially in, or near, infested areas.

Road systems and drainages are the main avenues by which *P. lateralis* invades new areas. The battery of management techniques available to the manager in new road construction and maintenance seeks to: 1) limit the likelihood that vehicles will pick up, carry, and deposit contaminated soil along roads and in cross drainages; 2) minimize direct movement of infested soil in road building and upkeep; and 3) where possible, decrease exposure of Port-Orford-cedars to roadside influences by design and location. Road treatments have been frequently suggested and used as parts of Port-Orford-cedar root disease management (Betlejewski 1994, Goheen et al. 1999, Hansen et al. 1999, Kliejunas 1994, Roth et al. 1987, Thies and Goheen in press, Zobel et al. 1985).

Figure 10.1—Surfaced roads reduce the likelihood of spreading *Phytophthora lateralis*

Use of road design, engineering, and maintenance techniques for Port-Orford-cedar disease management requires understanding and commitment by the organizations and individuals involved in the development, building, and maintenance of roads. Problems sometimes arise in emergency situations when quick repairs are needed.

Many of the road systems on federal lands were originally engineered and built when opportunities to incorporate Port-Orford-cedar root disease management treatments were not recognized. Such efforts as reshaping road surfaces for improving drainage, adding aggregate rock, paving, or improving stream crossings, are expensive. Cost limits their use. When considering upgrading roads to decrease risk of *P. lateralis* spread, the possibility that road improvements will encourage much greater road use can be considered and weighed in determining whether or not to implement the project. Greatly increased road use may offset disease management benefits achieved by the treatments.

Road management techniques may be less effective under the checkerboard ownership pattern that is found on most western Oregon BLM lands and many northern California Forest Service lands. In western Oregon, on BLM-administered lands, many roads are covered by Reciprocal Right of Way Agreements (fig. 10.2). These agreements are legal contracts that may constrain road management techniques. BLM roads covered by these agreements require concurrence from the private entity that is party to the agreement prior to any road management activity implementation not specifically addressed in the agreement.

Reciprocal Right-of-Way Agreements (RWAs) have played important roles in the administration of the Oregon and California Act (O & C) lands of western Oregon since the early 1950's. A RWA is basically an exchange of access rights between a private timberland owner and the United States. In a RWA, each party grants to the other the right to construct roads on the other party's land and the right to use existing roads for certain purposes owned or controlled by the other party. Guaranteed access to Federally-owned timber offered for sale by the Bureau of Land Management encourages competitive bidding among private timber companies. The rights granted or received in a RWA are for forest management activities and the transportation of forest or mineral products. A RWA does not necessarily include access rights for the public. Each RWA is unique, bounded by the applicable laws and regulations in place at the time the RWA is signed.

Although BLM roads are available for use by the public, they are not "public roads" as defined by State statute ORS 386.010(2). BLM roads are considered "private government roads" and the agency retains the authority to control activities on these roads including use by the general public. BLM roads are subject to closure by the agency for public safety and environmental protection reasons. An example would be closure during periods of extreme fire danger. The BLM requires permits for the use of these roads for commercial purposes. Terms and conditions of a RWA cannot be modified without approval by both parties to the agreement.

Figure 10.2—Reciprocal Right of Way Agreements

Water Source Selection and Treatment

Once *P. lateralis* has been introduced into a stream or body of water, there is always the possibility that propagules of the pathogen can be taken up and transferred with water from that source. Propagules are especially likely to be numerous if current or recent root disease-caused mortality and decline in cedars is readily detectable adjacent to the water; but they also may be present even in areas where all mortality appears to have occurred years previously. If water is taken only from sources that exhibit no evidence of root disease, probability of spreading propagules of the pathogen in water is reduced. Using water from uninfested sources for forest use has been suggested as a component of Port-Orford-cedar root disease management (Goheen et al. 1999, Hansen et al. 1999, Roth et al. 1987).

Many water sources have been inventoried and those that are potentially infested by *P. lateralis* have been identified. Subsequently, when water is needed for activities such as road construction, fire fighting, or dust abatement, uninfested water sources can be used when possible. Where disease-free water sources are not available and water must be taken from a potentially infested source, it can be treated with Clorox® Ultra Institutional before use (1 gallon of Clorox® to each 1,000 gallons of water). In areas where water sources have not been inventoried, Clorox® can also be used.

Adding chlorine bleach to *P. lateralis*-infested water will kill many propagules of the pathogen. Murray et al. (1995) demonstrated that complete mortality of *P. lateralis* zoospores occurred after 60 minutes in 100 parts per million (ppm) chlorine bleach, and complete mortality of chlamydospores occurred after 30 minutes in 5000 ppm chlorine bleach. Clorox® is registered for use in forest environments in California and Oregon.

Chlorine bleach, however, will not kill *P. lateralis* in infected rootlet fragments at any concentration (Murray et al. 1995). If mud is stirred up to any extent before an intake hose is placed into the water, suspended organic particles containing *P. lateralis* propagules may be taken up in spite of precautions taken with placement of the hose. Risk is minimized when bottom disturbance is avoided.

Regulating Non-Timber Uses

A number of special use activities including Port-Orford-cedar bough collecting, mushroom picking, salal gathering, grazing, and mining occur on federal forest lands and have potential to influence the spread of *P. lateralis*. Several of these activities involve extensive vehicle travel, and can involve vehicle movement from infested to uninfested areas. And some, especially bough collecting and mushroom hunting, are preferentially engaged in at times of the year when the cool, wet conditions most favorable for spread of the pathogen prevail. There is considerable anecdotal evidence associating bough collecting with the spread of *P. lateralis*.

Concerns about spreading *P. lateralis* with special use activities are similar to those associated with forest management projects, but special use activities are much more difficult to regulate.

The following permit restrictions may be selected by managers to help to minimize the spread of *P. lateralis*:

- specify where activities can be done;
- regulate the sequence of operations;
- determine the appropriate timing of activities with the objectives of limiting Port-Orford-cedar root disease spread;
- inform permitees about the disease and the need to cooperate with disease management requirements.

Difficulties associated with controlling special use activities include:

- lack of cooperation by some permitees;
- difficulty in tracking often widely scattered, transient, non-systematic operations
- language barriers with some workers;
- shortages of trained agency personnel for monitoring activities and enforcing regulations;
- laws that limit the degree to which some activities can be regulated on public lands (example: mining).

Recreationists, including hikers, mountain bike riders, horseback riders, hunters, off-road vehicle users, and campers also have potential to spread *P. lateralis*. Those involved in these pursuits are more difficult to monitor and regulate than special use permitees. Federally-sanctioned recreation activities may have specific, enforceable rules aimed at decreasing risk of disease spread.

Educational Efforts

Humans are responsible for most of the spread of *P. lateralis*. Many people inadvertently aid its spread due to lack of knowledge and understanding. A surprising number of forest users, including forest workers as well as recreationists, are not aware of the significance of the pathogen's adverse impacts on the forest. Some know about Port-Orford-cedar root disease but do not fully appreciate the implications of their own activities in spreading the disease organism.

Federal agencies are making extensive efforts to disseminate information on the biology and ecology of *P. lateralis*, with emphasis on how the pathogen spreads and how its spread can be prevented. Presentations at training sessions, workshops, and symposia, as well as newspaper articles, television interviews, pamphlets, journal articles, displays at public functions, classroom teaching materials, and information signs at BLM offices, Ranger Stations, visitor information centers, campgrounds, trail heads, and along forest roads are used.

Problems associated with current educational efforts include:

- difficulties in convincing people that their individual activities really can have effects on spread of the root disease organism (the "who me?" syndrome);
- difficulty in reaching the groups most in need of receiving the information, for example, off-road vehicle users or miners;
- problems disseminating information to non-English speaking individuals;
- challenges associated with making material interesting and/or readable;
- getting needed information across to large numbers of people within a short time period or with a limited amount of written material.

Of particular importance in the educational effort is reaching federal, state, and county agency employees. Not only do these employees spend considerable amounts of time in the forests where the spread of Port-Orford-cedar root disease is of most concern, members of the public also frequently observe them. If informed employees follow management direction for minimizing the spread of *P. lateralis*, they will directly influence others, encouraging them to do the same. Their examples will also demonstrate the commitment of the agencies to follow their own recommendations.

Prescribed Fire Potential

Use of prescribed fire as part of Port-Orford-cedar root disease management has been discussed, but not thoroughly investigated. In theory, fire could decrease or even eliminate *P. lateralis* on a site by killing hosts, as well as reducing or eliminating inoculum in the soil.

Use of fire for vegetation management or hazard reduction is routinely prescribed in many forested areas. Fire is a natural disturbance agent in many plant communities where Port-Orford-cedar occurs; prescribed fire may mimic the less severe, natural disturbance events that occurred historically.

Large Port-Orford-cedar trees are thick-barked, fire resistant, and can survive fire as well as mature Douglas-fir; young Port-Orford-cedar, however, are readily killed by even low intensity fires (Zobel 1990). *P. lateralis* does not infect dead trees, and killing all hosts in a strategic location is the basis for the sanitation treatments described later in this chapter. In certain situations, prescribed burning may be a way to accomplish this objective, especially when only small cedars are to be treated. Fire is being tested as a way to treat or retreat roadside sanitation segments where Port-Orford-cedars have reseeded in substantial numbers. Another potential treatment is the application of extremely hot water.[25]

P. lateralis itself is very sensitive to heat. It has been demonstrated that survival of the pathogen is minimal in soil exposed to temperatures of 104° F or greater, especially if conditions are dry (Hansen and Hamm 1996). If prescribed fires can generate temperatures in this range at sufficient depths in the soil to reach roots and organic material that are harboring the pathogen, it could significantly reduce or eliminate *P. lateralis* inoculum. In one trial (DeNitto 1992), soil baiting[26] was used to evaluate the effects of fire on *P. lateralis* in soil following a fire. In this case, the fire was of low intensity and temperatures did not exceed 100° F at a depth of 4 inches. The pathogen was recovered after the fire at the same level as before treatment. Effects of higher intensity fires have not yet been evaluated. Burn areas with substantial amounts of woody material, especially material that is greater than three inches in diameter, can be expected to generate higher intensity fires than that evaluated by DeNitto.

If prescribed burning proves effective and is implemented as a Port-Orford-cedar root disease management tool, certain precautions could be taken:

- use uninfested or treated water and equipment;
- units will be sequenced so that all uninfested units are treated before infested units in a project;

[25] Casavan, K. 1999. Personal communication. Natural Resource Specialist, Roseburg District Office, 777 Garden Valley Boulevard, Roseburg, OR 97470.

[26] Baiting is a type of bio-assay that uses Port-Orford-cedar seedlings to determine the presence of *Phytophthora lateralis*. Non-resistant Port-Orford-cedar seedlings are planted in soil or placed in streams where *P. lateralis* is suspected to occur. After an exposure period of four to eight weeks, the seedlings are recollected and examined for cambial stain, a diagnostic symptom of infection by *P. lateralis*. To confirm the diagnosis, root tissue from a subsample of seedlings is cultured on a selective media and examined under a microscope for the sporangia characteristic of *P. lateralis*.

- fire lines around prescription areas could be constructed using techniques that do not cause undesired changes in drainage patterns;
- fall or remove trees or snags to facilitate burning.

Genetic Resistance Breeding Development

An intriguing, long-term potential disease management option is the development of Port-Orford-cedar that are resistant to *P. lateralis*. Development of resistant Port-Orford-cedar stock could be especially valuable to managers attempting to restore the species in heavily impacted riparian areas. Host resistance has proven to be an especially effective disease management technique for use against many other *Phytophthora* species (Erwin and Ribeiro 1996, Umaerus et al. 1983). In 1989, evidence of resistance in natural Port-Orford-cedar populations was first demonstrated at Oregon State University (Hansen et al. 1989), and the Forest Service and BLM are now actively involved in a resistance enhancement-breeding program.

Results of the breeding effort so far are encouraging; however, there is no guarantee that usable resistance will result. There are several factors that will determine whether or not resistant Port-Orford-cedar will be used. These include: 1) durability of resistance; 2) practicality of producing stock (cost); 3) match of resistant material to appropriate seed zones and sites; 4) mechanisms of resistance involved, and, in some cases; 5) quality of resistant trees (e.g., form, growth rates). Managers with different objectives will have different priorities for these factors, but each will probably be concerned with most or all.

Port-Orford-cedar resistant stock will not be immune to *P. lateralis*. Rather, it will tolerate infection. If such stock is planted on an infested site, some level of infection will occur, and inoculum will be maintained even though many planted trees survive. Therefore, there is some concern about establishing resistant trees in certain situations. For example, in infested areas adjacent to heavily used roads, planting resistant stock might maintain inoculum that could be picked up and spread by vehicles. In such cases, having no Port-Orford-cedar would be better. Another example would be adjacent to uninfested natural stands where resistant trees could act as inoculum bridges, allowing spread of the pathogen.

Specific Management Techniques

Vehicle Exclusion

Vehicle exclusion is a quarantine technique that may be used to protect Port-Orford-cedar by preventing vehicle entry. If a manager chooses this technique, new roads are not built in uninfested areas, and existing roads are permanently closed (fig. 10.3). Road closures are done in ways that vehicles cannot broach them or detour around them. Large berms, “tank traps,” or rock piles are strategically located at sites where it is virtually impossible to bypass them (fig. 10.4). Alternatively, roads may be completely obliterated.

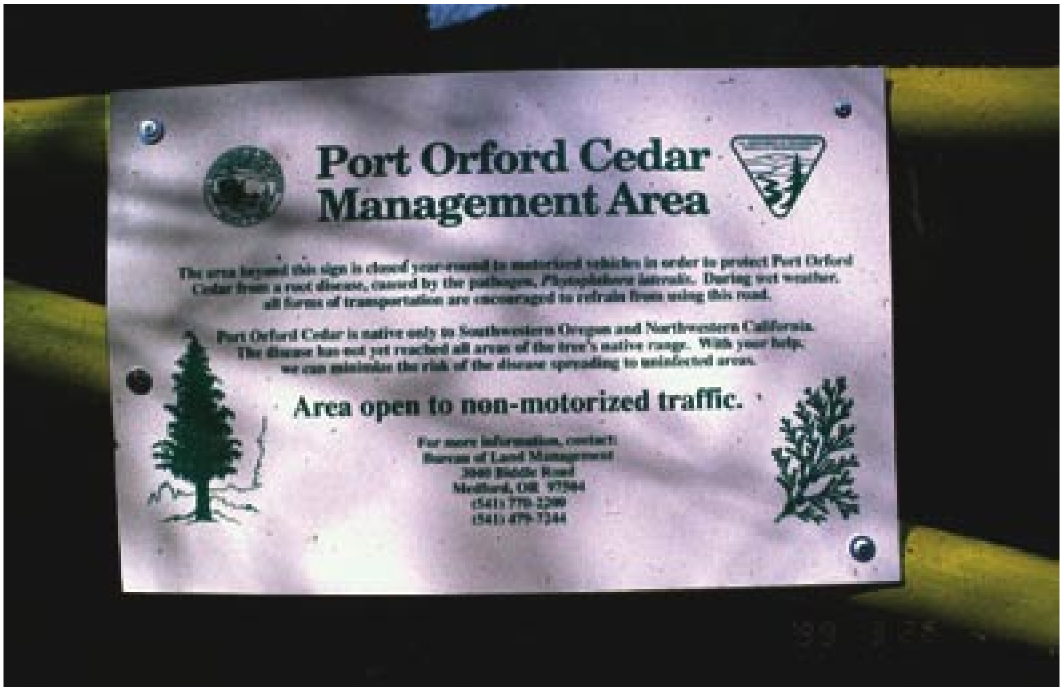

Figure 10.3—Road closure sign

Figure 10.4—Road closed to prevent the spread of *Phytophthora lateralis* (permanent closure)

If vehicle exclusion is selected, to be truly successful it should be practiced in a location that can be protected. Effectiveness has not been documented by systematic monitoring, but is supported by numerous, long-term observations.

When selected as a management technique, exclusion is best used where an entire drainage, or at least the upper portion of a drainage, can be treated as a unit. Exclusion is not likely to be useful in the lower portions of drainages if the upper portions are not also protected. Closing individual roads to prevent spread at lower elevations makes little sense if other roads higher up in the same drainages remain open.

Exclusion can be a controversial management technique. Some sectors of the public consider prevention of vehicle access to constitute an infringement on their rights to use public lands. Closing already existing roads is particularly unpopular. Legal precedents may make closing some roads difficult or impossible. Closing roads is often not an option, particularly where federal lands occur in checkerboard patterns interspersed with privately owned lands. Right-of-Way agreements that govern use of these roads usually prevent agencies from unilaterally denying access to land owners who have previously entered into a right-of-way agreement.

Temporary Road Closures

Like exclusion, temporary road closure (fig. 10.5) seeks to protect Port-Orford-cedar by preventing vehicles from spreading *P. lateralis* propagules into uninfested areas. It differs from total exclusion by allowing controlled road use into vulnerable areas during times when conditions are unfavorable for establishment and spread of the pathogen. If a manager chooses this technique, roads are closed during the cool, wet season of the year, typically from October 1 to June 1. In addition, special closures may be applied during particularly wet periods at other times of the year (June through September). Roads can be closed with locked gates, guardrails, or other movable barriers, and closures are located in areas where they are difficult to bypass.

Figure 10.5—Road closed to prevent spread of *Phytophthora lateralis* (temporary closure)

Temporary road closures require considerable attention to ensure that they are indeed in place when they need to be (during wet, cool periods at any time of year) and that they are not breached. Placement and strength of barriers are important considerations in use of temporary closures, as is constant vigilance. Because roads are still present beyond the closures, people in some areas have found ways around the closures, or have forced open or destroyed gates or other structures to gain access. Gate vandalism and the associated costs of repairing or replacing gates can be a major drawback of this technique.

Closing roads during the cool, moist season in uninfested areas keeps the probability of disease introduction and spread low. Research has demonstrated that successful spread and establishment of *P. lateralis* occurs when moist conditions prevail and temperatures are between 50° F and 68° F. These functions decline greatly as temperatures increase to 79° F and, under dry conditions, there is little activity of the organism at any temperature. Under dry, warm conditions, even survival of chlamydospores is greatly reduced (Hansen and Hamm 1996, Ostrofsky et al. 1977, Trione 1974, Tucker and Milbrath 1942).

Because of these temperature and moisture requirements, initiation of new *P. lateralis* infections occur almost entirely in the rainy and cool late fall, winter, and early spring months and very little in the warm, dry months. Flexibility to close roads during the summer months if unusual wet, cool conditions develop can further reduce probability of spread. Temporary road closure has been widely suggested as a Port-Orford-cedar root disease management technique (Betlejewski 1994, Goheen et al. 1997, Goheen et al. 1999, Hadfield et al. 1986, Hansen and Hamm 1996, Hansen and Lewis 1997, Hansen et al. 1999, Harvey et al. 1985, Nielsen 1997, Roth et al. 1987, Thies and Goheen in press, Zobel et al. 1985).

Roadside Sanitation

Roadside sanitation is a potential management technique that eliminates Port-Orford-cedar in buffer zones along both sides of a treated road (fig. 10.6). Silviculture texts define sanitation as “the elimination of trees that have been attacked or appear in imminent danger of attack by damaging insects or pathogens in order to prevent these agents from spreading to other trees” (Smith 1962, Daniel et al. 1979).

Figure 10.6—Roadside sanitation treatment to help prevent the spread of *Phytophthora lateralis*

The objectives for sanitation treatments are either 1) preventing new infections along roads that cannot be closed in currently uninfested areas; or 2) eliminating or minimizing the amount of inoculum readily available for vehicle transport from already-infested roadsides. The key feature of a sanitation treatment with either objective is to create a zone where live Port-Orford-cedar roots are absent.

Roadside sanitation is believed to be effective because *P. lateralis* only infects living hosts. The pathogen can survive in the roots of dead trees that were infected while alive, but it cannot colonize the roots of already dead Port-Orford-cedars. Therefore, if all living Port-Orford-cedars are killed in an infested area and establishment of new host regeneration can be prevented, the amount of inoculum should progressively decrease on the site and eventually disappear. Hansen and Hamm (1996) demonstrated that *P. lateralis* could survive in dead infected roots for up to seven years under ideal environmental conditions; under more typical conditions it probably survives four years or less.

To be most effective, sanitation treatments need to be thorough and based upon a prioritization of treatment areas. Much depends on the quality and completeness of the job. In any sanitation project, the actual treatment should be conducted with the utmost care to avoid the possibility of spreading the pathogen via the operation itself. Precautions such as timing treatments in the dry period of the year, treating uninfested areas first, keeping equipment clean, and not allowing vehicles used in the operation to travel from infested to uninfested areas without washing, can be standard. The importance of continued monitoring to determine if or when treated areas need re-treatment cannot be over emphasized.

Girdling, cutting, pulling, or burning may kill Port-Orford-cedar. Ideally, if roadside sanitation is applied, all Port-Orford-cedars of any size adjacent to the road are treated. The general buffer width recommendation is 25 feet above the road or to the top of the cutbank. Below the road, suggested treatment width is 25 to 50 feet with greater distances where streams or drainages cross the road or where amount of road fill is particularly substantial, resulting in especially steep slopes. Local conditions may make recommendations outside of this general range appropriate.

Sanitation treatments need to be repeated periodically to maintain roadside buffers free of Port-Orford-cedar regeneration. The preferred approach is to monitor treated areas and re-treat them whenever Port-Orford-cedar seedlings 6 inches or taller are detected. The early establishment of other plants that out compete Port-Orford-cedar may also minimize roadside Port-Orford-cedar re-invasion.

Where a road runs through an uninfested area with Port-Orford-cedar, elimination of live cedar roots in a buffer along the roadside results in no live hosts close to spots where contaminated soil is most likely to fall off vehicles using the road. Zoospores, the propagules of *P. lateralis* that would most likely be spread away from a road, are delicate and vulnerable to desiccation. They are unlikely to reach and infect hosts beyond the buffer created in a sanitation treatment. Other spore types (chlamydospores or encysted zoospores) also have a greatly reduced probability of crossing a sanitation buffer. Roadside sanitation has been widely suggested for use in Port-Orford-cedar root disease management (Erwin and Ribeiro 1996, Goheen et al. 1997, Goheen et al. 1999, Hadfield et al. 1986, Hansen 1993, Hansen and Hamm 1996, Hansen and Lewis 1997, Hansen et al. 1999, Harvey et al. 1985, Kliejunas 1994, Nielsen 1997, Thies and Goheen in press, Zobel et al. 1985).

Some sectors of the public find sanitation treatments unpalatable because they entail removal of live individual Port-Orford-cedar to protect the population. There are also objections to the name "sanitation." Many believe that "sanitation" implies only removal of dead trees.

There is also concern about the effectiveness of sanitation treatments. Starting in 1997, the Southwest Oregon Forest Insect and Disease Service Center initiated an investigation to obtain more quantitative data to evaluate the effectiveness of roadside sanitation treatments. Preliminary results indicate significant decreases in inoculum three to four years following treatments of already infested road sections (see following case studies).

Some federally-administered lands are interspersed with private lands. Frequently, road traffic cannot be legally restricted and if sanitation is not done across property boundaries, the sanitation treatment becomes fragmented. Overall effectiveness can be reduced if non-federal lands remain untreated.

Sanitation treatments may also be valuable in other areas besides roadsides; for example, treatments in infested riparian zones or in infestation centers not associated with roads and streams where: 1) the infested area is limited and discrete; 2) the mechanism of spread in the area is understood and lends itself to treatment; and 3) significant populations of uninfected Port-Orford-cedar are at risk in proximity to the infested area.

Vehicle and Equipment Washing

If the manager selects this technique, vehicles and equipment are thoroughly cleaned to remove adhering soil or plant debris that may contain *P. lateralis* before moving them into uninfested areas (fig. 10.7) and conversely, washing them before leaving infested areas of the forest (figs. 10.8 and 10.9).

Figure 10.7—Cleaning rippers

Figure 10.8—Washing equipment to remove soil potentially infested with *Phytophthora lateralis*

Figure 10.9—Washing a log truck to remove soil potentially infested with *Phytophthora lateralis*

Vehicles that carry soil infested by *P. lateralis* are known to be by far the most important long-distance carriers of the pathogen. Vehicle washing has been widely suggested and used as a disease management technique (Betlejewski 1994, Goheen et al. 1997, Goheen et al. 1999, Hadfield et al. 1986, Hansen and Hamm 1996, Hansen and Lewis 1997, Hansen et al. 1999, Harvey et al. 1985, Jimerson 1994, Kliejunas 1994, Kliejunas and Adams 1980, Roth et al. 1987, Thies and Goheen in press, Zobel et al. 1985).

Location and design of washing stations are extremely important considerations. To reduce the potential for spread of *P. lateralis*, the following practices may be implemented:

- Locate washing stations as close as possible to infested sites. Ideally, vehicles would not travel for any substantial distance prior to being washed. Vehicles moving into uninfested areas may be washed miles away as long as they do not travel through infested areas to reach their destination.

- Locate washing stations in areas where run-off water has no chance of entering adjacent streams or drainages, or of threatening nearby cedars.

- Design washing stations so that vehicles that have been washed are not likely to be re-contaminated by passing through wash water that contains *P. lateralis* propagules on their way out of the station.

An evaluation to test the effectiveness of a vehicle washing treatment was conducted by the Southwest Oregon Forest Insect and Disease Service Center in June, 1999. This study, summarized later in this chapter, used Port-Orford-cedar as bait trees to test the effectiveness of a vehicle washing treatment following exposure to *P. lateralis*. Results indicated that there were large reductions in inoculum on the vehicles following washing.

A major problem with vehicle washing as a Port-Orford-cedar root disease management technique is the difficulty of applying it consistently to all vehicles. Managers have a degree of control over vehicles used in projects and can require vehicle washing in the project contract, but many other vehicles are outside of their control and may or may not be cleaned. Efforts are underway to encourage a variety of forest users to voluntarily clean their vehicles, both through education to convince drivers that vehicle cleaning is worthwhile and through access to agency sponsored or supported washing stations (fig. 10.10).

Figure 10.10—Vehicle washing station

Case Studies

Effectiveness Monitoring of Port-Orford-Cedar Roadside Sanitation Treatments in Southwest Oregon

(Marshall and Goheen 2000)

In 1997, the Southwest Oregon Forest Insect and Disease Service Center began monitoring four sites with a systematic sampling procedure using small, tubed Port-Orford-cedar seedlings as baits. The baits were out-planted in ten transects along a 0.25 to 0.50 mile segment of road at each site. Transects were located where introduction or movement of inoculum was likely (existing dead Port-Orford-cedar, stream crossings, swampy areas, pullouts, etc) and also at random points along the road. The baits were removed from the tubes and planted perpendicular to the road, on both sides of the road, beginning at the edge of the road and then periodically along the transect and into the adjacent stand beyond the boundary of the sanitized area. They were also planted in the roadside ditches above and below the intersection with each transect. At stream crossings with water present, seedlings were left in their tubes and secured in the channel with metal stakes. The locations of the baits were mapped so the transects could be re-sampled in subsequent years. Throughout the process, precautions were taken to avoid contamination such as scrubbing boots and planting tools in chlorinated water before planting each new seedling. Baits were left in the streams for two weeks, then retrieved and incubated in the tubes for four weeks. Planted baits were left on the site for six weeks and then all baits were examined for evidence of infection by *P. lateralis*.

As of 2001, 13 different sites have been monitored annually (including the original four). Two sites are infested but had not been sanitized, one was sanitized but is not infested and the other ten are infested and have been sanitized. Once transects are installed, the procedure is repeated with the baits in the same locations at approximately the same time each year. The intent is to monitor each site for at least 10 years.

Preliminary Results and Conclusions—There has been an overall decrease in the number of infected bait trees beginning in the third year after the sanitation treatment. Prior to treatment (year zero), an average of 24 percent of bait trees were infected. Five years after treatment, an average of 6 percent of bait trees were infected. In three years of monitoring at the infested site that has not been treated, the level of infection in the bait trees has remained between 14 and 22 percent. It is believed that the reduction of inoculum observed in areas that were infested prior to sanitation treatment suggests that treatments in such areas are indeed worthwhile.

Within transects, the location of infected baits has varied greatly from year to year. Location of viable inoculum is probably affected by the highly variable weather conditions during the spring in southwest Oregon. This affects soil moisture and temperature and the amount and temperature of water in streams and ditches, all factors that would affect the activity of the pathogen. In general, we have found the greatest number of infected baits in the roadside ditches. This suggests that these ditches function as traps for infested water. It means that design and maintenance of the ditches is an important component of managing roads to limit the spread of *P. lateralis*. Relatively few infected baits have been found near the outer edges of the sanitized areas.

In general, fewer infected bait trees were retrieved from streams than expected. Putting the seedlings in the stream with the tubes still in place may make it more difficult for infection to occur, or the high velocity of the water in many of the streams may make it unlikely for infection to occur during the short duration of the trial.

One shortcoming of this procedure so far is the difficulty and uncertainty of monitoring success of sanitation treatments in uninfested areas. The baiting technique is only accurate for identifying the positive presence of *P. lateralis*. This technique will not necessarily predict the absence of *P. lateralis* if the baits were not located in the right places to intercept the pathogen.

Effectiveness of Vehicle Washing in Decreasing Transport of *P. lateralis* Inoculum

(Goheen et al. 2000)

An evaluation to test the effectiveness of washing treatments was conducted by the Southwest Oregon Forest Insect and Disease Service Center on the Grants Pass Resource Area, Medford District, BLM, in early June, 1999. This study used a sample-based approach, using Port-Orford-cedar as bait trees to test the effectiveness of vehicle washing following exposure to *P. lateralis* inoculum in soil.

A muddy roadside in an area known to be infested with *P. lateralis* was selected as an exposure site. Two vehicles, a road grader and a pickup truck, and a pair of high top rubber boots were intentionally exposed to the mud in the infested area by driving or walking through the site. Following the exposure, the vehicles and the rubber boots were washed separately at two staged wash sites; the first wash site was 50 feet up the road from the exposure site, and the second was located 100 feet up the road from the first wash site. The length and intensity of each wash was comparable to operational washing treatments currently being used in Port-Orford-cedar root disease prevention projects. Samples of the wash water from the first and second wash were collected by placing ten gallon plastic tubs below the test vehicles and boots; one tub was partially filled with water directly from the tank to act as a control. Water from the second wash was collected in the same locations relative to the vehicles and the boots as with the first wash. The wash samples were transported to an incubation facility in Central Point where one-year-old Port-Orford-cedar seedlings were used as bait trees to test for the presence of inoculum in the various samples of wash water (20 seedlings per wash sample). After eight weeks, the seedlings were removed and examined for evidence of infection by *P. lateralis*. The seedlings exposed to water from the first wash of the boots averaged 65 percent infection while those exposed to water from the second wash showed 2.5 percent; seedlings exposed to water from the first wash of the pickup truck averaged 41.2 percent infection while those exposed to water from the second wash exhibited 3.7 percent; and seedlings exposed to water from the first wash of the road grader averaged 27.8 percent infection while those exposed to water from the second wash showed 2.2 percent infection.

This case study showed that an operational-type washing affected the amount of *P. lateralis* inoculum on vehicles and boots that were purposely exposed to infested soil. Although the inoculum was not completely eliminated, it was greatly reduced as a result of the first wash. It is possible that in moving from the first wash site to the second, the vehicle tires and rubber boots picked up additional inoculum left on the roadway by other vehicles passing through the infested area. The results also suggest that some places on the vehicles, such as the blade of the grader and the under side of the pickup truck, may be more difficult to clean completely with the type of washing treatments currently in use. Results of this case study support the use of vehicle washing as one treatment for reducing the probability of spreading *P. lateralis* from infested to uninfested areas. However, washing by itself should not be considered a completely effective treatment. Vehicle washing may be considered for use in combination with other treatments in an integrated Port-Orford-cedar root disease management strategy. The following recommendations were included:

- Locate and design vehicle washing stations to reduce the likelihood of vehicles being re-contaminated by passing through wash water containing *P. lateralis*, and where there is no chance of runoff water entering adjacent streams, drainages, or uninfested concentrations of Port-Orford-cedar. Washing stations should be located in well-drained areas where vehicles can be washed over rocks or gravel; wash ramps could also provide a good area for washing vehicles.

- When possible, use the most effective and techniques for cleaning hard to reach areas.

- A stiff bristle brush should be carried in each vehicle for cleaning boots. Footwear should be brushed vigorously to remove obvious adhering soil and mud before entering the vehicle to travel to a new location (fig. 10.11), especially when leaving an area with obvious current disease-caused Port-Orford-cedar mortality.

Managing Port-Orford-Cedar in Areas Not Favorable to the Pathogen

In spite of the virulence of *P. lateralis*, and the fact that it has spread widely along roads and streams through a good portion of Port-Orford-cedar's range, there are still considerable numbers of sites, many of them substantial in size, where naturally occurring Port-Orford-cedar are thriving. Cedar on such sites has escaped infection because the sites have characteristics that are unfavorable for spread of the pathogen.

Port-Orford-cedar can be preferentially managed on sites where conditions make it likely they will escape infection by *P. lateralis*, even if the pathogen has already been established

Figure 10.11—Boots are cleaned to avoid spreading *Phytophthora lateralis*

nearby or may be introduced in the future. Port-Orford-cedar on low-risk sites--above and away from roads, uphill from creeks, on ridgetops, and well-drained locales-- are likely to survive.

Maintaining existing Port-Orford-cedar on low vulnerability sites such as convex slopes and ridge tops above roads has been commonly suggested as a disease management technique; actually developing "cedar production areas" by planting and actively managing Port-Orford-cedar on sites with such characteristics has also been suggested (Goheen et al. 1997, Goheen et al. 1999, Hadfield et al. 1986, Harvey et al. 1985, Hansen et al. 1999, Koepsell and Pscheidt 1994, Nielsen 1997, Roth et al. 1987, Thies and Goheen in press, USDA 1983, Zobel et al. 1985).

Maintaining natural Port-Orford-cedar on low risk sites has not been well evaluated, but field observation strongly indicates its success. *P. lateralis* is clearly capable of killing most, if not all, Port-Orford-cedar that it infects, so the widespread occurrence of healthy hosts throughout the cedar's range is a testimonial to the fact that naturally occurring trees on many kinds of sites do, indeed, escape infection.

Managing Port-Orford-Cedar in Areas Favorable to the Pathogen

Within infested sites that have characteristics particularly favorable for *P. lateralis* spread, observations show that some Port-Orford-cedar escape infection because of the microsites where they occur. Even what appear to be very slight microsite differences (elevated areas of only a few feet) can greatly influence the likelihood of infection. Spread of the pathogen from tree to tree, particularly around the margins of infestation centers or areas where overland flow of water is somewhat channeled, is also influenced by the spacing of Port-Orford-cedar and location of individual trees. Some spread is known to occur via root grafts between cedars; grafting potential has been shown to decrease substantially when Port-Orford-cedar are 18 feet or more apart on flat ground and five feet or more apart vertically on steeply sloping ground (Gordon 1974, Gordon and Roth 1976).

Distances between trees may also influence spread of *P. lateralis* via zoospores in water. Zoospores are quite delicate and can swim only short distances (1.2 to 2.4 inches) in standing water though they can be carried considerable distances in moving water (Carlile 1983, Hansen and Lewis 1997). If trees are outside of drainage channels and are widely spaced, they may escape infection. Wide-spacing and consideration of microsites in determining where to plant or maintain natural Port-Orford-cedar has been suggested (Hadfield et al. 1986, Harvey et al. 1985, Roth et al. 1987).

Port-Orford-cedar can be favored in plantings and thinnings on microsites that are unfavorable for the pathogen within infested areas (especially mounds and other high places) or, conversely, not favored on microsites optimal for infestation (close to and below roads, in or very close to streams or drainage ditches, and in low lying wet areas). Port-Orford-cedar may be planted or retained in thinnings in mixed species stands at wide spacing (25 feet or more between individual trees) (Harvey et al. 1985, Hadfield et al. 1986).

Manipulating Species Composition

Favoring tree species other than Port-Orford-cedar that are appropriate for local sites is especially applicable where *P. lateralis* is already established or in sites that are particularly favorable for future establishment of the pathogen.

P. lateralis is host-specific and most tree species that grow within the range of Port-Orford-cedar do not become infected (Zobel et al. 1985). Only Port-Orford-cedar and occasionally Pacific yew (*Taxus brevifolia*) are infected by *P. lateralis* under natural conditions (DeNitto and Kliejunas 1991, Erwin and Ribeiro 1996, Hepting, 1971, Murray and Hansen 1997, USDA 1992). Planting alternate species has been suggested (Filip et al. 1995, USDA 1983) and has been done in some areas that have been severely impacted by *P. lateralis*.

Management Challenges

Some particularly formidable challenges associated with Port-Orford-cedar root disease management on federal lands are listed below.

Difficulty of Monitoring Effectiveness of Management Activities

Effectiveness monitoring of Port-Orford-cedar root disease management activities is extremely difficult. Frequently, monitoring has been subjective. A treatment may have been rated as fully effective, partially effective or not effective. This type of monitoring is not especially useful; it is not quantitative and cannot be statistically analyzed. What constitutes an "effective" treatment has not been standardized. Ideally, effectiveness is based on lack of new infections in an area, but in some cases it may be based on whether or not the treatment was installed effectively, i.e., a gate remains free of vandalism or all Port-Orford-cedar are indeed removed in a sanitation treatment. Optimally, to evaluate treatment effectiveness, sample-based monitoring that determines *P. lateralis* presence and abundance on a site after the treatment, is required.

In spite of past research efforts, no accurate, inexpensive, and quick soil assay technique for *P. lateralis* has been devised that can be used easily in the field. Baiting, using Port-Orford-cedar seedlings as described in the Southwest Oregon Forest Insect and Disease Service Center's road sanitation monitoring effort, is the best technique currently available (Goheen and Marshall, in press). It is fairly inexpensive and accurate, but takes up to two months to provide results. It can be installed with a design that lends itself to statistical analyses.

Few Opportunities to Obtain New Management-Related Research Results

Although public and federal agency interest is great, and opportunities for investigating new management techniques or using research to test effectiveness of established techniques abound, there are few researchers working on Port-Orford-cedar root disease or on management related questions. Funding for research on Port-Orford-cedar and *P. lateralis* is essential for the success of the programs.

Public Opposition to Agency Management Activities

Federal agencies have found that keeping all sectors of the public informed and, when possible, supportive of the agencies' Port-Orford-cedar root disease management is an important but difficult task. Environmental groups were instrumental in developing awareness of the seriousness of the disease and the importance of managing it. But some of these same groups actively oppose agency management because they do not believe the techniques being employed will be effective. Some believe that only exclusion or permanent road closures are worthwhile strategies.

Coordination Difficulties

Although coordination has improved in recent years among public land management agencies, each agency has different regulations, management agendas, emphasis areas, and administrative rules. A challenge is associated with trying to coordinate activities with private landowners. Many landowners do not cooperate because maintaining Port-Orford-cedar is not an important objective for them, because they are worried about the costs, delays, and inconveniences associated with such management efforts, or because they fear that cooperation may lead to future regulations that would impact their abilities to manage their own lands as they see fit. Such lack of cooperation can severely decrease the effectiveness of federal Port-Orford-cedar management or limit its success to only parts of a landscape.

Funding Uncertainties

Many Port-Orford-cedar root disease management and research activities are expensive. Both the Forest Service and the BLM have maintained funding for root disease management efforts on federal lands at a reasonably high level for the past few years. Funding for research, however, has been more difficult to obtain. A considerable proportion of root disease management support for both agencies has come from national Forest Health Protection funds (U.S. Department of Agriculture). To qualify for such funding, local managers must apply annually and compete against other proposed disease management projects from throughout the country. Agency managers are concerned about the dependability of future Port-Orford-cedar root disease management and research funding.

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