

Wildland Management of *Phytophthora ramorum* in Northern California Forests¹

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Abstract

In early 2006 we implemented a series of comparative silvicultural treatments aimed at managing the spread of *Phytophthora ramorum* Werres, de Cock & Man in't Veld by reducing inoculum densities in isolated infestations on one public and three private properties in southern Humboldt County. These treatments, which took place on over 56 forested ha, are the first attempts at large-scale, stand-level silvicultural management of *P. ramorum* in California. As part of first-year post treatment monitoring, we compare a number of issues related to operational effectiveness of the treatment installations, such as identifying areas for treatment, barriers to treatment, timeframes, expense, equipment and vehicle sanitation, and public perception of treatments. These are issues to be considered by anyone attempting silvicultural treatment of this pathogen in the future.

Key words: *Phytophthora ramorum*, California, forest, management, silviculture.

Introduction

Wildland management of *Phytophthora ramorum* in California forests has generally been limited to a few small-scale projects. To date, the efforts have focused on preventing pathogen establishment by the use of phosphonate fungicide on individual oak trees (Garbelotto and others 2003) or the use of prescribed fire to remove understory hosts (Kent Julin, personal communication, 2006). By comparison, a larger-scale eradication program has been implemented in Oregon that involves use of herbicides (to prevent sprouting), host tree removal (to remove inoculum and pathogen reproduction), and pile burning infected materials (to sanitize the site) (Goheen and others 2004).

Phytophthora ramorum is currently established in a range of coastal California forest types, and the tools for managing the pathogen are not equally applicable to all of these forest types. Furthermore, the social acceptability of these tools is a critical component of implementation success. In forest areas already infested with the

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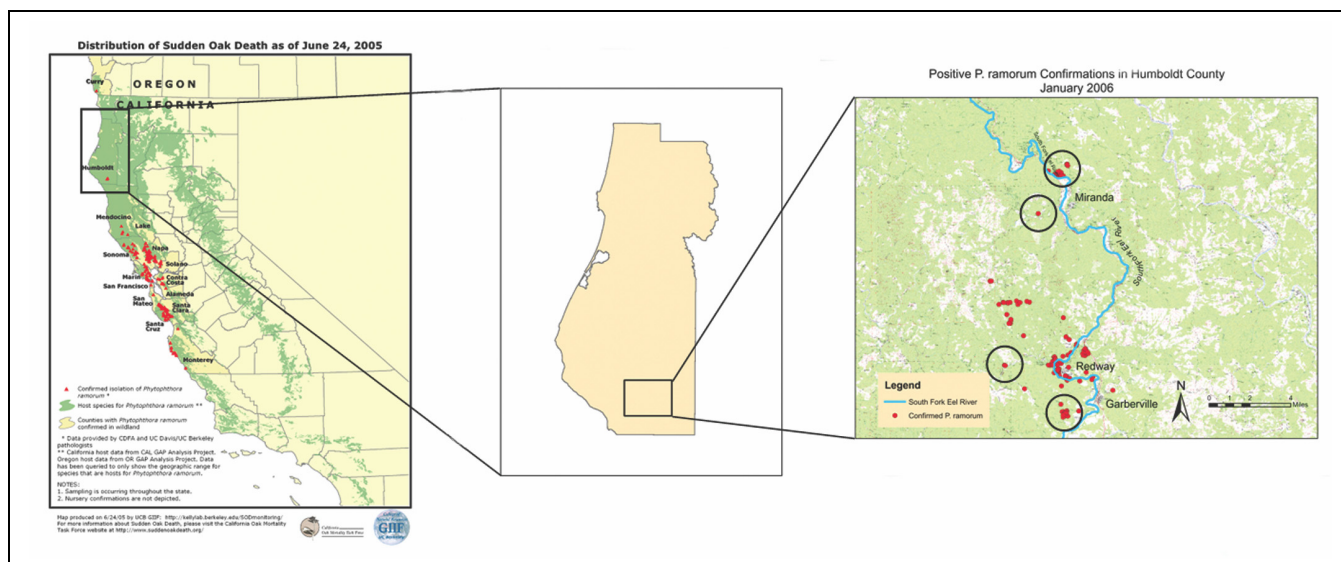
disease, more information is needed to better understand if it is possible to suppress inoculum production or slow the spread of the disease and to develop a range of long-term management recommendations for landowners and managers of forested properties. The goal of the study is to find treatment options that are socially acceptable, financially affordable and biologically effective in controlling the pathogen.

Materials and Methods

In Humboldt County, California, *P. ramorum* has been limited to one geographic region, in the South Fork Eel River watershed, presumably emanating from the area of the first report of the organism in 2002 in the understory of an old-growth redwood (*Sequoia sempervirens* [D. Don] Endl.) forest adjacent to the small town of Redway. Following an initial control effort in 2004 that involved removal of infected California bay laurel (*Umbellularia californica* [Hook. & Arn.] Nutt.) trees, the only known host at the time in the area, interest in managing the pathogen in this area geographically isolated from the rest of the *P. ramorum* distribution in California has been increasing. Since this initial find in the Redway area, a group has formed to implement an aggressive early detection program utilizing stream baiting, aerial reconnaissance, public education and targeted ground surveys.

Using information about areas infested with the pathogen, we developed a control strategy that prioritized installation of treatments to areas that were small (<20 ha) and on the outside of the core infested area around Redway. We reasoned that these areas represented advancement of the disease front within the county. The strategy envisaged a long-term disease suppression campaign resembling the effort involved in large-scale fire suppression, in which personnel attack “hot spots” that flare up outside the main body of the fire while performing a holding action on the main body.

We identified four areas (fig. 1) for treatment as a part of this adaptive management strategy in November 2005. These four areas comprised three privately owned



Figure—1. *P. ramorum* distribution in California and Humboldt County, and areas prioritized for treatment.

parcels and one publicly owned parcel. Prior to treatment, we established permanent monitoring plots for pre- and post-treatment data collection (circular, 0.04 ha in size, uniformly distributed in a 100 m X 100 m grid over each property) to provide an approximately 5 percent area sample. On these plots, we collected data characterizing vegetation conditions at the stand level (for example plant species present; numbers of and presence of symptoms on trees, saplings and seedlings; tree diameters; overstory canopy closure; basal area). Treatment implementation took place from January through May 2006.

The overall treatment program involved removal of the two main hosts involved in sporulation and aerial transmission of the pathogen, California bay laurel and tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehd.) (Rizzo and others 2005). This removal resulted in changes in stand structure designed to reduce humidity levels and understory host material. The specific treatments (table 1) included manual removal by chainsaw and pile burning of branches and foliage of all bay and tanoak, with and without subsequent underburning, replicated on three properties in October 2006. Additional, unreplicated smaller case-study treatments on the properties involved the removal of bay and tanoak using herbicides and thinning according to a standard fuels reduction prescription modified to include removal of all bay trees. These treatments were tested in two different but common forest vegetation types in northern California (table 1).

Table 1—Comparison of specific treatments, goals, effectiveness, and costs, one year after treatment

Treatment ⁶	Goals	Effectiveness	Costs	
			Public Lands	Private Crews
bay + tanoak ^{1,2}	Remove abundant inoculum	Numerous saplings and seedlings left	\$617.50/ ha	\$4940-8645/ ha
bay + tanoak + broadcast fire ^{1,2}	Remove abundant inoculum, fire to consume seedlings, saplings, litter	Fire consumed saplings, seedlings, litter	\$988/ ha	\$4940-8645/ ha
herbicide bay and tanoak ²	Remove abundant inoculum + prevent sprouting	Tanoak died in 3 months, Bay alive 14 post treatment	NA	\$617.50/ ha
fuel hazard reduction + bay ²	Test common treatment, girdle large diameter bays	Residual tanoak alive, except near girdled bays that are still alive 10 months post treatment	NA	\$4940-6175/ ha

⁶ Comparison of forest stand conditions (Sawyer and Keeler-Wolf 1995) where treatments were tested, in superscript.

¹ Redwood alliance with some co-dominant Douglas-fir and a secondary story of mixed evergreen hardwoods;

² Douglas-fir-tanoak alliance with a secondary story of mixed evergreen hardwoods. The first, second, and fourth treatments listed in the table involved manual removal of tree species accompanied by hand piling and burning of branches and foliage. The herbicide treatments did not involve processing of branches or foliage.

Given that it can be very costly to remove large bay trees and process their abundant foliage and that the trees sprout from the root collar after being cut, we tested two alternative treatment methods: the use of herbicides to kill trees in place and to prevent future sprouting, and girdling in place. The herbicide treatments involved a syringe-based injection of imazapyr in February 2006 (the earliest we could treat after finding the disease on the property in November 2005), since direct application via injection has been found to be the most effective method of imazapyr delivery for control of tanoak (DiTomaso and others 2004) and is much less costly than making future entries to control sprouts. Applicators spaced hatchet frills for herbicide injection every 7.5 cm on tanoaks and every 2.5 cm on bays, with 1 mL of chemical injected into each frill. Two forms of imazapyr were used, Arsenal® on upland trees and Habitat®, an aquatic formulation of the same chemical, for trees in riparian areas. To girdle large bays, crews cut into the trees with chainsaws to a depth of 15 cm around each entire tree in two locations approximately 0.3 to 0.6 m apart and used axes to completely remove all cambium and phloem tissue between the two cuts. The bay trees were girdled in May 2006.

We will ascertain pathogen persistence by assessing disease symptoms on new sprouts and seedlings of host trees each year for at least two years after treatment. The current assessment of these adaptive silvicultural projects reflects the state of our knowledge one year after treatment. So far we have conducted one-year post-treatment monitoring on one treatment area. More data will become available over time.

Results and Discussion

Approximately 1 year has lapsed since the beginning of treatment on these project areas. At this time we know some information about the effectiveness of the treatments, but more about the costs and challenges of implementing them.

Challenges for Implementation

A first challenge is that silvicultural management of bay and tanoak must take account of these species' ability to sprout following tree removal. By the end of the summer 2006 the cut bay and tanoak trees had sprouted in all treatment sites, in some cases reaching heights over 2 m tall. To our surprise, most bay logs left on the treated areas had also sprouted, although by the end of the summer, they had lost their vigor and had begun to die. We conducted 1-year post-treatment monitoring on one treatment area in February 2007. In one of the largest sites treated, the crews had a limited time window for operation (see below), and as we expected the crews were not able to remove all of the small diameter (<2 cm) host material. We found that the broadcast burn was an effective tool for removing this small-diameter material. In the unburned sites with more small-diameter host stems left, we do not know whether these stems will significantly contribute to aerial dispersal and spread of the pathogen, though we will continue to monitor these sites for new symptom development. Our one-year post-treatment assessment in one of the four treated areas (mentioned above) has so far found that new sprouts of tanoak and bay do not show signs of the pathogen. Kanaskie and others (2005) found that new tanoak stump sprouts could become infected following treatment. At this point we believe that it is too early in the season to draw conclusions about new infections of sprouts and seedlings. It may take several years to evaluate effectiveness of these treatments.

Initial management projects of disease infestations require the determination of specific boundaries of the infested areas. This is particularly challenging in the case of *P. ramorum*. In all cases the infested areas were a part of the larger forest, and there were no clear ecotones that would suggest logical boundaries for treatment areas. As part of our strategy to define the area for treatment, we carefully surveyed the areas surrounding infected trees for symptoms, primarily on bay leaves, and sent symptomatic material to the University of California Davis Rizzo lab for diagnosis. Once we were able to map general locations of the pathogen with the results from the laboratory testing, we conducted detailed field work to find exact perimeters where symptoms stopped. As noted by others (John Bienapfl, personal communication, 2005), it is particularly difficult to use symptoms on tanoak as an indicator of *P. ramorum* infection; where bay is present, symptomatic bay leaves serve as the best indicator of likely *P. ramorum* infection, even though several other pathogens cause similar symptoms.

Another consideration is timing of treatment operations, which in our studies was limited by both wildlife restrictions and rapid disease spread. In three of the four treatment areas, we lacked sensitive wildlife species data and so had to abide by all nesting restrictions for wildlife that could potentially occupy these sites. One of the treatment areas was determined to be potential habitat for the marbled murrelet, *Brachyramphus marmoratus* (Gmelin, 1789); this required that noise-producing (for example, chainsaw) work be completed before the start of breeding season on March 23rd, and it delayed prescribed burning until after the end of breeding season (September 15th). As a result, we had to change our projected spring burn into a fall burn, when fewer crews are available and air quality restrictions increase, so that the actual prescribed burn differed from the one originally planned. Treatment timeframes are also limited by *P. ramorum*'s rapid spread. Effective control requires an excellent early detection and rapid response team. Even with good early detection, however, quick management response can be limited by lengthy contracting and environmental review processes that do not support emergency action. At this point in California, the presence of *P. ramorum* in forested areas has not constituted an emergency situation.

Besides dealing with the difficulties of timing treatments, land managers performing operations designed to manage *P. ramorum* must also consider sanitation to avoid pathogen transmission off the site. Cushman and others (this volume) and Tjosvold and others (2002) demonstrated that soil taken from hikers' shoes contained *P. ramorum* inoculum, while Cooper and Cushman (2006) found that *P. ramorum* incidence is higher in areas with high human visitation and activity. For the silvicultural treatments detailed in this study, we mandated that crews scrub the bottoms of their boots and wash them in a 10 percent bleach solution before returning to their home bases as well as thoroughly cleaning chainsaws, brush chippers, chaps, and other equipment with compressed air, brushes, brooms, and manual inspection for clinging foliage. Additionally, landowners of some of the parcels on which treatment occurred improved the parking areas for crew vehicles by lining the parking areas with new gravel or rock so that the vehicles could avoid parking in mud and crews would have a cleaner surface for their personal sanitation. Land managers planning *P. ramorum* management operations should take into account the additional time and expense involved in these kinds of activities.

Crews

Phytophthora ramorum management, in our experience, is only effective to the degree that crews are brought up to speed and supervised effectively. For all crews, there is a learning curve associated with each project because the treatments utilized non-traditional prescriptions and because prescriptions varied between sites. We were not able to use the same crew on each of the project areas, for scheduling, financial and/ or political reasons. As a result, costs varied between projects (table 1). For example, the California Department of Corrections has low-cost fire crews that are available for work on public properties, but these crews are not available for use on private properties, nor are they available in all locations in California. While these crews were less expensive than private crews, they did require more on-site supervision by project designers, the costs of which are not reflected in table 1.

Costs

As with all silvicultural treatments, costs vary with the complexity of the project. In our situation, costs probably increased by the addition of sanitation requirements and the development of non-traditional prescriptions; however, increasing experience with treatment implementation on the part of supervisors and crews will probably lessen these costs over time. The most obvious cost at this time is that associated with processing large infected bay trees and the unknown status of new bay and tanoak sprouts. We sought to reduce these costs by testing two alternatives to cutting trees down by chainsaw. In neither situation did we find a satisfactory alternative. In the case of the herbicide work, bay trees within all size classes are still alive fourteen months after treatment, albeit with yellow leaves and thinned crowns. We are still able to recover the pathogen from these leaves, and presumably the spores can still spread the pathogen. More information is needed about whether there are socially acceptable and biologically effective alternative herbicide(s) to kill infected bay trees. Additionally, it has been 10 months since large bay trees were girdled, and their crowns show no difference in color and vigor from crowns of untreated trees. Use of herbicides or girdling by chainsaw to kill bay trees may be appropriate in areas where the pathogen is not present or where a rapid (i.e. <4 month) treatment effect is not needed.

The most complex treatment in this study, the treatment involving removal of all bay and tanoak trees, is probably too expensive for most land managers to implement in the bulk of the *P. ramorum* infested area of California. However, where expectations for control are higher, especially where the infested areas are small (<2 ha), the cost may be bearable. It is important to note that these treatments produced no commercial products. While we did leave logs on site that could be utilized for firewood, there is potential risk for pathogen transmission in the movement of infected tanoak logs (Parke and others 2007), so firewood use should not be considered.

Public Perceptions

Finally, the land manager dealing with *P. ramorum* must consider public perceptions of treatment. Our active management of *P. ramorum* reinforces our educational message concerning the pathogen in the north coast of California by demonstrating that landowners and land managers are concerned enough about the spread of the disease to take action. This area of California features a relatively high level of

ecological knowledge and concern among its residents; therefore, most of the landowners that we approached with suggestions for treatment offered enthusiastic support, which was augmented by an active stakeholder consultation process, quick notification to landowners of disease detections on their properties, and regular communication with neighbors. Additionally, actively managing this pathogen often foregrounds more general forest health issues for landowners and motivates them to practice better stewardship of their properties. These silvicultural management activities facilitated many non-disease-related goals, such as road improvement, conifer restoration, and fuels reduction on treated properties.

Although we have discovered that landowners display great enthusiasm for *P. ramorum* management, they do not equally accept all possibilities for treatment. What is acceptable for a landowner usually depends on the particular goals and objectives for ecosystem management on that property, some of these codified by law or agency policy. Forests in this area under California Department of State Parks ownership, for example, could not be treated with herbicides; likewise, we have encountered some private owners averse to herbicide use on their properties, partly because of community antipathy toward such use. Conversely, some other owners accept herbicide killing of hardwoods as an accelerated route toward conifer restoration on their land. Treatment on some properties may preclude prescribed burning because of location and air quality concerns, while other landowners may impose maximum diameter limits on the removal of bay and tanoak trees. Since public opinion of recommended treatments is a determining condition of future management work, this must be taken into account when judging treatment effectiveness.

Conclusions

In summary, evaluating treatment effectiveness will take several years and must consider a variety of biological, social, and economic factors, some of which are measurable now, while others are not. Of the treatments tested, costs were generally quite variable (e.g. 620 to \$8,645/ ha). Treatment implementation was constrained by a variety of wildlife issues and landowner preferences. On the least expensive side, the herbicide and girdling treatments tested to control bay trees were not effective in the desired timeframe; as a result, testing of additional bay control strategies is needed. The effectiveness of the most expensive treatment, full removal of infected bay and tanoak trees with broadcast burning, is not known to date, but this treatment does show the greatest quality and uniformity of host removal. While the costs of this treatment are very high, it may be palatable in areas of exceedingly high risk or where standards for success are high. At this point it is generally too early to recommend one treatment type versus another. However, it is clear that if the pathogen is left unmanaged, the area infested and impacted in California will continue to grow (Rizzo 2007).

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