

Testing and Implementing Methods for Managing *Phytophthora* Root Diseases in California Native Habitats and Restoration Sites¹

Tedmund J. Swiecki² and Elizabeth A. Bernhardt²

Abstract

Over the past 14 years, a variety of native plant communities in northern California have been identified where introduced root-rotting *Phytophthora* species, most notably *Phytophthora cinnamomi*, *P. cambivora*, and *P. cactorum*, are causing decline and mortality of native species. In many older infested sites, the source(s) of the original *Phytophthora* introductions are not clear. Movement of contaminated soil is the most likely source in some sites that are located along roads and trails. In other cases, introductions are associated with plantings of nursery stock. In one site, a multi-species infestation (*P. cambivora*, *P. cactorum*, *P. 'kelmania'*, and *P. syringae*) extending over more than 2 ha was associated with the planting of 30 to 50 or more nursery-grown *Ceanothus* plants as part of a restoration effort. Once *Phytophthora* infestations become established, they have typically spread along roads and trails and downslope with surface water flow.

Samples taken from transplanted nursery stock in a variety of other habitat restoration projects planted between about 2000 and 2014 have yielded a wide variety of *Phytophthora* species (>50 taxa). These include species not previously found at field sites in the US as well as undescribed taxa (Bourret and others, Restoration outplantings of nursery-origin Californian flora are heavily infested with *Phytophthora*, these proceedings; Rooney-Latham and others, An update on *Phytophthora* species in California native plant nurseries and restoration areas, these proceedings). Sampling conducted to date suggests that the rate of spread of introduced *Phytophthora* species from planted stock varies widely based on site conditions and the *Phytophthora* species involved. Spread appears to occur more rapidly where roots of nearby host plants extend into the planting sites and where sites are at least seasonally inundated. Furthermore, baiting results have shown that propagules of some *Phytophthora* species can survive at least 1 to several years in the absence of a live host plant (including sites with either dead or previously removed plants).

The widespread use of *Phytophthora*-infested nursery stock in habitat restoration projects poses serious risks to many native plant communities. Unabated spread of *Phytophthora* infestations in the limited habitat of susceptible rare plant species, including Ione manzanita (*Arctostaphylos myrtifolia*) (Figure 1) and pallid manzanita (*A. pallida*), may drive the remaining natural populations of these species to extinction. Even where the affected plant species are not rare (e.g., madrone, giant chinquapin, valley oak), *Phytophthora* infestations can degrade and permanently alter native vegetation. Many *Phytophthora*-affected sites no longer support the range of native species that were previously present, including keystone species.

¹ A version of the paper was presented at the Sudden Oak Death Sixth Science Symposium, June 20-23, 2016, San Francisco, California.

² Phytosphere Research, 1027 Davis Street, Vacaville, CA 95687.
Corresponding author: phytosphere@phytosphere.com.

Land managers and resource agencies seeking to manage these introduced pathogens in native habitats have very limited options. Management options are primarily related to the extent and characteristics of the infestation and can be grouped under the following approaches: eradication, active suppression, and prevention/slowing further spread. Options can be further constrained by other habitat-specific management concerns, site accessibility, cost, and feasibility issues. The adaptive management approach provides a good framework for developing an appropriate management plan (Swiecki and Bernhardt 2013). Under this approach, managers first determine what they have by assessing plant resources, disease conditions, and the current management framework. Based on this analysis, managers identify needs and set goals and objectives to meet those needs. The next step involves selecting and implementing management actions to meet goals and objectives. Goals may need to be revised if available management strategies cannot obtain desired outcomes. Once management actions are implemented, disease and plant health outcomes are monitored and analyzed to see if goals are being met, bringing the process full circle.



Figure 1—Stand of lone manzanita, *Arctostaphylos myrtifolia*, killed by *Phytophthora cinnamomi* in native habitat near Lone, California.

The preferred management option for all habitats is to avoid introducing *Phytophthora*. Over the long term, it is more effective, economical, and easier to prevent or avoid introductions than to attempt eradication or perpetually manage affected areas to minimize further spread. The risk of introducing *Phytophthora* through habitat restoration projects is nearly eliminated if plants are established by recruiting existing natural regeneration or via direct seeding, instead of using nursery stock. If nursery stock is used, it should be free of *Phytophthora* to the maximum extent possible. Best management practices (BMPs) for producing *Phytophthora*-free planting stock have been developed and are being adopted and implemented by agencies and native plant nurseries. Planting stock produced under these BMPs is acceptable for restoration use if no *Phytophthora* species are detected in the stock using the most sensitive testing protocol available. Testing should only be used as a final quality control check on plants that have been produced under rigorous clean production practices. Due to its limitations, testing should not be used in an attempt to find uninfected plants within an infested batch produced under inadequate phytosanitary practices.

Once *Phytophthora* has been introduced into an area, management options are limited and may not be completely effective. Eradication is the most desirable option, but is only feasible for very small areas,

such as spot infestations identified at an early stage. Recent installations of *Phytophthora*-infected nursery stock in habitat restoration areas represent sites where eradication may be possible if introduced *Phytophthora* species have not spread beyond individual planting sites. The ability of *Phytophthora* species to spread from infested sites in different types of planting situations is under investigation. For a number of *Phytophthora* species, we have found that eradication is not possible by simply removing infected host plants because of extended pathogen survival in soil.

Solarization of small areas (minimum of 1 m²) for extended periods (1 year or more) is being tested as a means of eradicating *Phytophthora* from individual planting sites. Sites have been covered with one or two layers of clear plastic thermal anti-condensate greenhouse film (0.15 mm [6 mil] thick) that has a 4 year service life rating. At *P. cactorum*-infested planting sites solarized for 7-15 months, the pathogen could not be recovered by baiting at sun-exposed sites, but was detected at sites that received significant shading. Temperature data suggest that the pathogen was not eradicated if sites did not attain at temperature of least 35 °C at 20 cm in depth, the depth of the container stock rootball. However, a side benefit of solarization appears to be inhibition of pathogen spread from contaminated sites. If the plastic film is intact, water from precipitation only reaches the soil under the plastic via capillary movement from the surrounding wetted soil; this situation is unfavorable for zoospore release and dispersal. We are also investigating other means for spot treating infested planting sites with heat. A steam injecting soil auger (Johnson 2014) and other related methodologies are being investigated.

Active suppression of disease using systemic oomycete suppressive chemicals (“fungicides”) may be possible in larger infested areas, but this tactic becomes less viable as the infested area increases. In habitat of lone manzanita infested with *P. cinnamomi*, the advance of mortality in affected stands has been suppressed for more than 4 years by treating plants at the edge of mortality centers with a foliar spray of potassium phosphite (12.4 kg ai/h applied at 300 L/ha in alternate years). Ultra low volume (ULV) foliar applications have greater potential to be of use in this habitat because affected areas are difficult to access with the large ground equipment needed for higher volume sprays. Results of initial ULV applications (8 or 10 kg/ha at 30 L/ha) were not promising, likely due to reduced rates needed to avoid phytotoxicity. More recent tests using two ULV applications in series at least 4 weeks apart (split application) totaling 16 or 20 kg/ha at 30 L/ha are underway and initial results are promising.

In large infested areas where active suppression is not feasible, management is generally limited to slowing further spread along the margins of the infestation and preventing contamination of non-infested areas via movement of infested soil. To accomplish this, it is necessary to delineate the extent of the infested area, at least approximately. This is accomplished through a combination of soil baiting and mapping symptomatic plants, but is more difficult in mixed vegetation types that include plants with varying responses to the pathogens present. Management methods employed at affected sites have included signage, permanent trail closures, specifying wet-season closures, preferred travel directions, altering road surface materials, and specifications for crews or contractors to minimize soil movement from infested areas. These measures have the potential to reduce the rate of spread along roads and trails and the development of satellite infestations, but do not slow unassisted pathogen spread from root to root or along drainages.

Literature Cited

Johnson, A.J. 2014. Evaluation of a steam injection auger system for the management of replant problems in California almonds (*Prunus dulcis*). Davis, CA: University of California. 51 p. M.S. Thesis.

Swiecki, T.J.; Bernhardt, E.A. 2013. A reference manual for managing sudden oak death in California. Gen. Tech. Rep. PSW-GTR-242. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 129 p.