Guidance for environmental regulators to reduce the risk of *Phytophthora* and other plant pathogen introductions to restoration sites

This paper provides guidance for regulators on how to address the risk of introduction and spread of *Phytophthora* and other pathogens in restoration site plantings and mitigation projects. These recommendations were developed by the Working Group for Phytophthoras in Native Habitats (www.calphytos.org) with input from land managers, regulators, restoration nursery growers, and plant pathologists gathered at a Restoration Committee meeting held October 2016 in Albany, CA.

Background

In 2014-16, well over 50 *Phytophthora* taxa were identified in native plant nurseries and restoration sites, including *P. tentaculata* and *P. quercina* (both new to the USA); *P. uniformis*, a first detection in a US nursery, as well as new hybrid species; and new taxa still being described. The incidence and number of new pathogen taxa detected raises concerns about outplanting of native plant nursery stock into sensitive habitats, where the plants can serve as a high risk pathway for introduction of plant pathogens into wildlands.

Container plant movement can spread Phytophthoras long distances and facilitate their proliferation across landscapes. Once an area is contaminated, it is difficult to eradicate the pathogen and restore lands. For example, the sudden oak death pathogen, *P. ramorum*, was introduced to wildlands on horticultural nursery stock resulting in the death of millions of trees along the California Central Coast and Southern Oregon. The inadvertent spread of exotic *Phytophthora* species into natural ecosystems is a threat to environmental, social and economic resources in restoration areas and adjacent wildlands. Restoration areas are conservation investments; those endowments and surrounding natural habitats are threatened by plant pathogen contamination.

To protect watersheds, and respond to new *Phytophthora* introductions, land managers suspended plantings, cancelled orders or invested millions in solarization and other treatments to clean-up contaminated sites but have achieved only partial eradication. Discontinuing restoration planting is not an ideal long-term solution to *Phytophthora* prevention since many of the benefits of restoration are lost or significantly delayed when nursery stock is avoided. Here we provide guidance for regulators to protect habitat in mitigation programs from *Phytophthora* infection and spread.

What are Phytophthoras? The genus *Phytophthora* (pronounced Fie-TOF-ther-uh) belongs to the Kingdom Stramenopila (formerly Chromista), which also includes aquatic organisms such as diatoms and kelp. The name "*Phytophthora*" derives from Greek and means "plant destroyer." There are currently more than 125 described species of *Phytophthora* worldwide. Commonly called "water molds", *Phytophthora* species produces swimming spores, called zoospores, and thrive under moist conditions.

Notorious Phytophthoras include *P. infestans* that caused the Irish potato famine of the 1840s, *P. cinnamomi* which infects more than 2000 plant species and is particularly damaging in Australian wildlands, and *P. ramorum,* cause of sudden oak death. *Phytophthora* species are among the most destructive pathogens of agricultural crops and forests in the world. There are no *Phytophthora* species that can be considered to be completely harmless, but *Phytophthora* species do show varying degrees of pathogenicity to different hosts and under dissimilar environmental conditions.

The concern for Phytophthoras in nurseries and forests is not new, but until recently we did not have data on the extent of infestation in CA native plant nurseries and restoration sites. There is little information on the risk of a particular *Phytophthora* species to a specific CA native plant host and ecosystem. The variability in environmental conditions (e.g. precipitation, soil type, topography, amount of disturbance), also increases the difficulty in defining risk. Due to the potential for irreparable, severe environmental damage to California's natural habitats, precautions to prevent pathogen introduction are warranted.

Goals and objectives

The purpose of this guidance is to assist regulators in the development of criteria that minimize the threat of *Phytophthora* contamination in restoration and mitigation projects while utilizing appropriate and measurable performance standards to assess project success.

> Objective 1: Recommend restoration design elements that reduce the risk of *Phytophthora* contamination and spread in natural areas.
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> Objective 2: Recommend changes to common success criteria that will accommodate the restoration design recommendations and accurately measure restoration success.
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> Objective 3: Provide phytosanitary best management practices for all phases of restoration implementation, monitoring, management, and maintenance.

Recommendations

The following practices may be useful to prevent pathogen contamination in restoration and mitigation projects:

1. Restoration Design Considerations:

A. **Allow designs with lower initial plant density**. Requiring large quantities of nursery plants to be installed increases the likelihood that some of those plants may be infested with *Phytophthora*. The greater the number of plants installed the higher the risk for pathogen introduction. Furthermore, the closer the plants are to one another the higher the likelihood of pathogen spread through root contact, overland flow or splash of contaminated water, or pathogen transfer from movement of contaminated soil during maintenance and monitoring activities. High cover requirements in the early years of a project can pressure the project proponent to plant in higher densities, which can inadvertently lead to increased disease transmission.

B. **Consider the use of direct seeding native plant seeds or cuttings instead of container stock**. Planting locally-collected seeds or cuttings rather than installing container stock can minimize the risk of introducing pathogens to a site.

C. **Allow flexibility in the project design.** Not all sites are the same and tailoring a restoration/mitigation project design to specific site conditions will ensure that the most appropriate methods are used, and will encourage the greatest chance of success for plant establishment.

2. Adapting Survivorship Success Criteria to Accommodate Direct Seeding:

Direct seeding at the site instead of installing nursery container stock could be a powerful tool to reduce *Phytophthora* contamination in restoration sites. However, individual plantings performance is commonly measured using a survivorship percentage which can result in penalties driven by aspects of direct seeding. Seeding requires multiple plantings, and survival of each planted seed or cutting is on average lower for direct seeded plantings in comparison to container stock which can adversely influence survivorship success criteria calculations. Below we suggest changes to the survivorship success criteria so restorationists are not penalized for utilizing direct seeding.

A. **Increase the time allowed for plant establishment.** By allowing for more time for a restoration site to establish, revegetation techniques like direct seeding and natural recruitment can be included in the design which have a

lower risk of pathogen introduction than nursery plant installation. Percent cover benchmarks and survivorship criteria may take longer to achieve with these alternative techniques, and may need to be met over a longer period of time. Adjust the monitoring frequency to accommodate the longer project time by reducing the monitoring frequency after establishment while increasing the overall monitoring period.

B. Allow for greater direct seeding mortality by reducing the required survivorship percentage success criterion. Use of direct seeding in a restoration/mitigation project may result in lower recruitment and greater mortality during the early establishment period; however, the plants that survive will likely be healthier and more successful than container stock in the long term. Direct seeding facilitates on-site natural selection, so surviving plants are better adapted to local hydrologic and edaphic conditions than container plants grown in nonnative soil.

When direct seeding methods are used, a project benefits from successive years of seeding to achieve different age classes of recruits. Monitoring and reporting requirements should allow flexibility in plant survival performance and success criteria to encourage direct seeding and cuttings. Not resetting the restoration start time after each round of planting would allow for repeated plantings without handicapping the performance or lengthening the project time.

C. Replace "survivorship percentage" with a fixed number of recruits required per habitat. Using a fixed number instead of a percentage will not penalize the restorationist for implementing multiple years of plantings.

D. Allow mitigation credit for natural recruits. In areas where adjacent remnant native vegetation exists or in native soils with a seed bank, natural recruits of native species may be better adapted to local site conditions and can result in a more successful restoration. Allowing a project applicant to receive mitigation (survivorship) credit for natural recruits would ensure that site specific vegetation is encouraged on project sites and would reduce the potential for installation of non-local plants or potentially contaminated container stock. Flexibility of plant establishment methods may prevent pathogen introduction and enhance the ecological health of the plantings. Naturally occurring recruits could be counted and protected in summer; the total number found would be added to the number of survived first year recruits that count towards the survivorship criterion.

3. Use best management practices in every phase of restoration, from design through to maintenance. Complete guidance is posted at www.calphytos.org, "Guidelines for Restoration Activities".

A. **Ensure the use of clean nursery stock**. To prevent and manage the introduction and spread of Phytophthoras and other plant pathogens during restoration activities, it is essential that projects use clean nursery stock grown with comprehensive best management practices. For detailed guidance on how to minimize *Phytophthora* pathogens in restoration nurseries, see The Phytophthoras in Native Habitats Work Group "Nursery Management Resources" at www.calphytos.org.

B. **Prevent contamination in site preparation, installation, performance monitoring, and maintenance.** Use of best management practices to prevent pathogen introduction and spread is also critical during all other phases of restoration to reduce contamination risk. For detailed guidance on how to prevent and manage Phytophthoras during various aspects of restoration, including nursery plant production, see The Phytophthoras in Native Habitats Work Group "Restoration Guidance" at www.calphytos.org. Restoration installation, maintenance and monitoring have potential for pathogen spread and introduction due to movement or use of non-sanitized vehicles, tools, footwear or inadvertent use of contaminated materials (e.g. soil erosion protection wattles and mulch, or non-sanitized materials recycled from other projects such as rebar, fencing materials, etc.).

Fundamental principles include:

A. Minimize project footprint and soil disturbance. Provide guidance in mitigation and monitoring plans and project designs to minimize soil disturbance. Keep the number of vehicle pass-throughs and other disturbances during site maintenance and monitoring activities to the least necessary. Avoid visits when conditions are wet, and areas are muddy. Park vehicles in designated staging areas.

B. Require sanitation practices. Phytophthoras and many other pathogens move when contaminated soil is transferred on vehicle tires, footwear, on the hoofs of grazing animals, on contaminated tools or infested plant materials. Require sanitation best management practices: tools, boots, and vehicles should be visibly free of soil before and after use.

C. Promote prevention through education. Check that agency staff and contractors are aware of the risk of inadvertent pathogen introductions on native plant nursery stock

and understand how to prevent pathogen introduction and spread. To promote early detection, personnel need to recognize disease symptoms and continually scout for problems. Reporting questions, problems or concerns needs to be encouraged and rewarded. A pre-project meeting that provides appropriate BMP training to all workers and oversight managers who will be onsite during the project will help avoid confusion and delays in the field and will ensure in advance that everyone is clear on the project goals related to pathogen prevention.