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# The Cross-Pollinator

*Connecting forested communities & delivering science for the trees outside your door*

## A Threat to Ecological Investments: Plant Pathogens in Landscape Restoration Projects

A biologist surveys for plant pathogens in a restored site at the Presidio in San Francisco. Courtesy photo by Presidio Trust, used with permission.

**EXECUTIVE SUMMARY**

- Brought inadvertently from other parts of the world, plant pathogens such as those in the genus *Phytophthora* have been commonly found on nursery stock grown for restoration and revegetation purposes in California.
- In California and elsewhere, these pathogens have been introduced to environmentally vulnerable and important restoration sites, often resulting in plant illness or death, along with the need for costly remediation.
- Restoration out-plantings of nursery-origin Californian flora are often infested with *Phytophthora*.
- Threatened species habitat is at risk when invasive plant pathogen species become established and spread into new areas.
- USDA Forest Service scientists and collaborators have created an organization called the *Phytophthoras* in Native Habitats Work Group to protect sensitive habitats and restoration sites against Phytophthora and other introduced plant pathogens in California and other high-risk regions around the country.
- More information on the Work Group can be found at www.calphytos.org.

### Risk to High-Value Habitats

To repair ecological damage caused by construction, landscape managers typically apply restoration techniques—but what if these activities further damage the ecology? This is an issue that USDA Forest Service scientists and their partners have worked to address since 2014, when they discovered that a water-mold pathogen called *Phytophthora* had been inadvertently introduced to restoration sites in the San Francisco Bay Area.

The microorganisms were brought to habitat restoration projects on native nursery stock, including a wide variety of trees, shrubs, and other perennial plants. These plant materials had been intended to mitigate environmental impacts of pipeline installations and repairs, as well as dam reconstruction and powerline extension projects.

Not only did these pathogens cause plant infection and illness, but they also further degraded habitat that had been intended to be restored. At various sites, they infested habitat for vulnerable species such as the shrub coyote ceanothus (*Ceanothus ferrisiae*), California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana draytonii*), and the mission blue butterfly (*Icaricia icarioides missionensis*). According to Susan Frankel, a plant pathologist for the Forest Service Pacific Southwest Research Station based in Albany, California, “The problem had been around for a long time, but it was unrecognized until about 6 years ago. For restoration projects, plant survival is often low, but it was assumed that the reason for the plant failures was due to site or

Other species of *Phytophthora* include *P. infestans*, a water mold that causes the potato and tomato disease known as late blight or potato blight. Licensed photo by Rasbak, https://en.wikipedia.org/wiki/GNU_Free_Documentation_License.

*"Especially in the beginning, it was quite shocking. We were placing these pathogens right where we didn't want them—in some of our most precious habitat."*

*–Susan Frankel, Pacific Southwest Research Station*

ecological factors. Pathogen detections in a few local restoration sites triggered an increase in native plant nursery surveys."

When the extent of infection was realized, there was shock and concern among vegetation ecologists and native plant growers, Frankel says, noting, "We were placing these pathogens right where we didn't want them—in some of our most precious habitat." Frankel and her partners are now providing leadership and technical guidance to assist the native plant and restoration community to solve this problem.

## The Plant Destroyer

The word *Phytophthora* comes from two Greek words that, when combined, can be translated as "plant destroyer." Frankel notes that Phytophthoras are among the most notorious of all plant pathogens. Although not all species are especially dangerous to plants, *Phytophthora* are capable of serious damage to crops, gardens, and natural ecosystems. Some species are more deadly and spread more readily than others because of their cold tolerance and ability to attack both roots and leaves. Particularly susceptible are woody ornamental species grown in nurseries, including rhododendrons and viburnums. Recently, *Phytophthora* has been found also on rushes and other plant types that were not previously associated with *Phytophthora* infection.

Nearly 200 *Phytophthora* species have been identified, including ***P. infestans***, which led to the potato blight that caused the Great Famine of Ireland. Another is *P. ramorum*, which has caused 'sudden oak death' in millions of trees in California and Oregon, as well as larch mortality in Europe. Hundreds of other unidentified *Phytophthora* species are believed to exist; they may be carried by infected plants, water, air, or soil, with potential impact to thousands of plant species. Symptoms include dieback, collar rot, root rot, fruit rot, cankers, blight, and often death. There are a few limiting factors. For example, upland, drier areas with well drained soils are typically less conducive to *Phytophthora* establishment and spread. Nurseries have been battling *Phytophthora* for decades, and the disease can be difficult to detect and control in nursery settings.

Once introduced to the soil and water of a natural area, *Phytophthora* species are nearly impossible to eradicate by any means unless the infestations are extremely localized. Programs to develop plant resistance can take decades, during which time a new pathogen or hybrid may overcome whatever resistance has been developed.

## An Ounce of Prevention ...

To protect sensitive habitats and restoration sites against *Phytophthora* and other introduced plant pathogens, Frankel and others created an organization called the Phytophthoras in Native Habitats Work Group (www.calphytos.org). Formed in 2015, the Work Group is a coalition of native plant nursery managers, land management agencies, researchers, and nonprofit organizations. Its aim is to minimize spread of *Phytophthora* pathogens in restoration sites and native plant nurseries by coordinating a comprehensive, unified program entailing management, monitoring, research, education, and policy.

Modeled after the California Oak Mortality Task Force (www.suddenoakdeath.org), the Work Group has developed a variety of resources, including guidelines to prevent *Phytophthora* in restoration nurseries, which are typically defined as businesses that grow or procure native plants for ecological restoration.

The spread of *Phytophthora* is a problem that could easily worsen around the country, especially since infections in horticultural and landscape nurseries have been reported for decades. "Although the Pacific Northwest has relatively high damage potential because it's so

Insulated solar ovens bake soil to eliminate *Phytophthora* without sterilizing beneficial microorganisms. Courtesy photo by Janell Hillman, Santa Clara Valley Water District, used with permission.

> *"By following a few simple guidelines, facilities with widespread contamination have been able to reduce their* Phytophthora *occurrence to zero."*
>
> *–Matteo Garbelotto, University of California, Berkeley*

moist, *Phytophthora* introductions via restoration nursery stock could occur nearly anywhere," Frankel says, adding, "It's less likely to occur in the middle of a desert, but even Reno, Nevada, has *Phytophthora* street tree infections."

Nursery stock shipments also present a risk for pathogen movement. In spring 2019, rhododendrons originating at a few West Coast nurseries infested with *P. ramorum* were inadvertently shipped for sale to Midwestern big box retailers. Despite quarantines to prevent such shipments, federal and state regulators reported that potentially infected plants were shipped to 28 states. The shipments were tracked down by agricultural inspectors and attempts were made to destroy the plants. Regional high risk areas for *Phytophthora* include the Pacific Northwest, Mediterranean ecosystems in California, Midwest oak ecosystems, Southeast ecosystems, and commercial Christmas tree production in North Carolina and elsewhere.

To combat new infections, the Work Group has produced nursery best management practices, essentially suggested guidelines that include instructions related to monitoring and testing, and sanitizing containers, potting media, tools, work surfaces, and more. The Work Group is also developing an accreditation process for restoration nurseries. According to Professor Matteo Garbelotto, director of the Forest Pathology and Mycology Laboratory at University of California, Berkeley, and Work Group member, "By following a few simple guidelines, facilities with widespread contamination have been able to reduce their *Phytophthora* occurrence to zero." Frankel agrees, saying, "All growers that use these guidelines report that not only do they have fewer *Phytophthora* detections but overall their crop is more robust."

## … And a Pound of Cure

The Work Group also provides various forms of assistance in cases where *Phytophthora* has been introduced to natural areas. One natural area infestation that helped add to the Work Group's knowledge base occurred in Santa Clara County in 2014. When Valley Water (the Santa Clara Valley Water District) planted a new population of endangered coyote ceanothus shrubs on a ridge near Anderson Dam, a few hundred container plants—obtained from a commercial restoration nursery—were found to be universally infested with *P. cactorum*, which causes root rot.

Because the Anderson Dam site was remote and included a variety of sensitive habitats such as grey pine woodland, serpentine grassland, and mixed-sage chaparral, remediation was complicated. However, the site's pristine nature meant that full remediation was imperative. With Work Group guidance, a layer of greenhouse film was layered over planting basins to heat the soil and successfully eradicate the pathogen. In shadier areas, the soil was dug up and cooked in solar ovens.

To mitigate for a planned seismic retrofit of Anderson Dam, Valley Water is establishing a new population of endangered coyote ceanothus shrubs using phytosanitary procedures. Courtesy photo by Janell Hillman, Santa Clara Valley Water District, used with permission.

As a result of the remediation, today Valley Water has transformed how it sources plants for restoration efforts. "We only work with nurseries that follow the best management practices to reduce pathogens to the best extent possible," according to Janell Hillman, a senior biologist and plant ecologist for Valley Water. These practices, largely based on those developed by Ted Swiecki and Elizabeth Bernhardt at the research and consulting firm Phytosphere Research, are available at www.calphytos.org.

The Anderson Dam project remediation cost hundreds of thousands of dollars and applied innovative treatments that the Work Group documented for future cases. But the most important takeaway was the need to avoid contamination in the first place. According to Hillman, "It's a lot easier to avoid actions that may cause harm, because once you do, it can become very complicated and expensive to remedy." Swiecki agrees, saying, "As opposed to species of *Phytophthora* that are transmitted aerially, the root-rotting *Phytophthora* that we're addressing tend to be slow motion disasters. They may take a decade or two to be noticed, and by that time it has most likely spread through the soil and there's very little you can do to eradicate it. It's much better to prevent the pathogen from being introduced to a site in the first place."

Following the cleanup, Valley Water conducted direct seeding and container plant installation, this time following strict phytosanitary guidelines for growing, planting, and maintaining nursery stock. According to Hillman, "We now test all our plants prior to delivery from the nursery. We also have new policies for planting that we require our contractors to follow. Just being clean from a phytosanitary perspective—at all stages of a restoration project—can greatly contribute to restoration success." About 800 coyote ceanothus plants have been installed at the site and the project is back on track to meet its requirements.

This case also caused local land managers to take a closer look at their nursery stock. "Anderson Dam has some areas that were restored decades ago that show *Phytophthora* still slowly spreading and killing plants," Frankel explained, adding, "Those contaminations were overlooked and unnoticed until the detection of *P. cactorum* made people stop and look."

## Problems at the Presidio

Another example of an outbreak occurred in the Presidio of San Francisco, a 1,500-acre National Park on a former military post. A heavily used outdoor recreation hub, the Presidio has forested areas, trails, a golf course, scenic overlooks, beaches, plus museums, homes, restaurants, and businesses. The Presidio's forest and designed landscape zones have been planted with nursery-grown plants for more than a century and much of the native habitat zone has been restored using nursery-grown plants since the late 1990s. These nurseries provide approximately 150,000 container plants annually for habitat restoration projects throughout the Golden Gate National Recreation Area, which includes the Presidio.

Researchers monitor coyote ceanothus at the Coyote Ridge mitigation site in Santa Clara County, California. Courtesy photo by Janell Hillman, Santa Clara Valley Water District, used with permission.

The discovery of Phytophthora in 2014 at San Francisco's Presidio led to prompt testing, remediation, and implementation of best management practices. Courtesy photo by Presidio Trust, used with permission.

*"We only work with nurseries that follow the best management practices to reduce pathogens to the best extent possible."*

*–Janell Hillman, Santa Clara Valley Water District*

In 2014, land managers learned of *Phytophthora* infestations in Presidio nursery plants. Testing of more than 1,000 root and plant samples found *Phytophthora* in 88 percent of all tested sites. Fourteen *Phytophthora* species were found, including one that had not been previously detected in the United States. This was an alarming discovery, according to Frankel, who explained, "Most of our concern is for plant populations or habitats of limited extent or very high value. For example, in the Presidio, they had only one individual of a particular manzanita species and it was found to be infected with *Phytophthora*."

Best management practices were quickly implemented. Workers heat-treated potting-soil, improved drainage in growing areas, and sterilized plant containers, footwear, tools, and equipment. According to Alisa Shor, park nurseries director at Golden Gate National Parks Conservancy, "We run four nurseries and it's now a daily practice for our team to keep our nurseries clean. Our operations have forever changed. We're not a lab and there are lots of environmental factors that we can't control, but we've had tremendous success in keeping *Phytophthora* out of our planting areas."

In addition, off-road vehicles, which can spread the pathogen, were restricted during the rainy season and improvements were made to visitor education, volunteer outreach, trailside signage, and even how trail-covering material is handled. Shor goes on to say, "Realistically, this is more work and it's more expensive. However, improvements can be made in increments—you don't have to retool overnight. There are simple things that can be done initially and that can start you on the way. But best management practices in nurseries are well worth it. They have also had an unexpected benefit in the health of our plants: Overall crop health has improved noticeably."

## A Ray of Hope and a Bunch of Dog Treats

In these cases, continuous monitoring and improved management practices have shown a dramatic reduction in *Phytophthora* detections. In the meantime, the Work Group and its partners continue to refine and develop ways to prevent *Phytophthora* spread. At UC Berkeley, Matteo Garbelotto runs a project that has successfully trained dogs to identify different species of *Phytophthora* in contaminated soil and water. This research is continuing, to see if dogs can recognize the pathogen from individual infected plants and plant parts and discriminate its smell from other scents. Garbelotto is also encouraged by the widespread collaboration he has seen so far. "Large land management agencies and the regulatory and scientific worlds have all come together to recognize the importance of this issue, to apply resources to it and to develop best practices," Garbelotto says.

Yet there is still much to be done. According to Frankel, "There are several messages that we want to get out, since a lot of people don't know about this issue." The first is that restoration efforts are being affected by this pathogen. The second is that it can happen elsewhere. Frankel says, "My expectation is that with the movement of plant material around the world, climate change, and other stressors, *Phytophthora* will continue to be a concern over a wider geographic area." A third message Frankel hopes to share is that a collaborative, adaptive management approach is needed to cleanup infested areas. Additional information and resources by groups including the Forest Service, the National Fish & Wildlife Foundation, and the California Native Plant Society can be found at www.calphytos.org. Finally, Frankel wants land managers and nursery teams to know that the USDA Forest Service is providing leadership, technical assistance, and a structure to deliver science-based solutions that will sustain plant health by responding to these plant pathogen introductions in restoration areas.

### NURSERY BEST PRACTICES

**According to the "Guidelines to Minimize Phytophthora Pathogens in Restoration Nurseries" developed by the Work Group for Phytophthoras in Native Habitats, the best defense against *Phytophthora* becoming established in wildlands is to prevent their inadvertent introduction via infested nursery plants. To keep this from happening, the document provides detailed instructions for the following guidelines:**

- **Keep planting materials clean. Start with propagative material that is free from infection or external contamination by *Phytophthora* species as well as other possible pathogens.**
- **Keep containers clean. Use only clean containers to eliminate these as a potential source of pathogens.**
- **Keep potting material clean. All potting media must be pathogen-free and be handled and stored in a manner that precludes contamination.**
- **Keep water clean. Use only uncontaminated, appropriately treated water for irrigation.**
- **Maintain clean production practices. Prevent contamination of initially clean plant materials by consistently following an integrated set of comprehensive phytosanitary working practices.**
- **Keep detailed records. Maintain records that verify that inputs are clean, that nursery workers are complying with clean production practices, and that facilitate traceability of materials used for the production process.**
- **Deliver clean finished plant material. Follow phytosanitary procedures to maintain clean stock until it has been transferred to the customer.**
- **Use appropriate sanitizing materials and treatments while understanding the appropriate uses and limitations of each treatment**

## MANAGEMENT IMPLICATIONS

- *Phytophthora* pathogens are a threat to restoration efforts. Recent cases in California identified that contaminated plants had been obtained from local nurseries.
- Introduction of plant pathogens on restoration stock can be prevented through use of best management practices in production nurseries.
- Restoration nursery accreditation for clean stock shows promise to prevent plant pathogen introductions.
- *Phytophthora* infestations have been reported in several regions of the United States, including parts of the Midwest and Southeast. Broadly applicable resources such as best-practice guidelines for restoration stock production nurseries can be found at www.calphytos.org.

## FURTHER READING


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## ADDITIONAL RESOURCE

The Phytophthoras in Native Habitats Work Group recently received a 2020 California Department of Pesticide Regulation IPM Innovation Award.

This 2.5 minute video shows some of the group's work.

Watch the video. [https://www.youtube.com/watch?v=CfljdfUJaJU&feature=youtu.be].

## SCIENTIST PROFILES

**SUSAN FRANKEL is a biologist with the Pacific Southwest Research Station in Albany, California. She received a bachelor's degree in natural resources from the University of California, Berkeley, and master of forest resources degree in forest pathology and silviculture from the University of Washington, Seattle. Her research interests include forest Phytophthoras; invasive species management; climate change and forest diseases, urban forest health, and tracking pest trends. Additional information on Susan can be found at www.fs.fed.us/psw/programs/efh/staff/sfrankel.**

**MATTEO GARBELOTTO is an extension specialist in forest pathology and mycology and adjunct professor at University of California, Berkeley, Department of Environmental Science, Policy, and Management. He received his bachelor's degree in forestry from the University of Padua, Italy, and a master's degree in silviculture and forest pathology in 1990. He received a master's degree and Ph.D. at UC Berkeley. Matteo's research interests include the effects of changes in forest ecosystems on the evolution and ecology of forest pathogens. Additional information on Matteo can be found at ourenvironment.berkeley.edu/people/matteo-garbelotto.**

**TED SWIECKI is a principal at Phytosphere Research in Vacaville, California. He holds a bachelor's degree in biology from the University of California, Riverside, and a Ph.D. in plant pathology from the University of California, Davis. His research and consulting activity has focused on maintaining healthy plants and ecosystems in natural and urbanized landscapes. He specializes in prevention and management of diseases of California native oaks and other plants. More information on his research can be found at phytosphere.com.**

**ELIZABETH BERNHARDT is a principal at Phytosphere Research in Vacaville, California. Elizabeth received a bachelor's degree in plant pathology at the University of Wisconsin, Madison, and earned a master's degree and a Ph.D. in plant pathology at the University of California, Davis. Her research and consulting activity has focused on maintaining healthy plants and ecosystems in natural and urbanized landscapes. She specializes in prevention and management of diseases of California native oaks and other plants. More information on her research can be found at phytosphere.com.**

**JANELL HILLMAN is a senior biologist/plant ecologist and plant pathogen program manager for the Santa Clara Valley Water District (Valley Water), where she has worked for more than 20 years. She received a bachelor's degree in environmental studies at the University of California, Santa Cruz, and a master's degree in biology from San Francisco State University. Much of her work centers around understanding the conservation biology of rare and endangered plants on serpentine soils and sensitive natural communities and developing recovery strategies for them.**

**ALISA SHOR is the director of park nurseries for the Golden Gate National Parks Conservancy in San Francisco.**

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## PURPOSE

The Cross-Pollinator is a science synthesis publication produced quarterly in cooperation between the Northern Research Station, the Urban Field Station Network, State and Private Forestry, and the Urban Forest Technology and Science Delivery Team. It spotlights transdisciplinary collaborations among researchers and practitioners that "cross" forest research with urban and community forests at a landscape scale.

## ABOUT US

The mission of the Urban Field Station Network is to improve the quality of life in urban and urbanizing areas by conducting and supporting research and science exchange about social-ecological systems and urban-to-rural resource management. The mission of the Urban Forest Technology & Science Delivery Team is to work collaboratively to deliver quality urban natural resources science, technology, and information to improve the long-term sustainability of urban ecosystems and the broader watershed, for wildlife and people. Find out more at https://www.nrs.fs.fed.us/ufs/; https://www.fs.fed.us/research/urban-science-delivery-team.php; and https://www.vibrantcitieslab.com/

## CONTACT INFORMATION

For more information or to sign up to be notified of future issues, visit https://www.fs.fed.us/research/cross-pollinator/. For questions, comments, or feedback, contact the editor:

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