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Sudden Oak Death Guidelines for Arborists

A plant disease known as Sudden Oak Death is threatening coastal forests in California and Oregon. Currently found in 14 coastal counties from Monterey to Humboldt and in a small portion of southwest Oregon, the disease is caused by the pathogen *Phytophthora ramorum*. Sudden Oak Death has resulted in the death of over a million tanoak, coast live oak, California black oak, Shreve oak, and canyon live oak trees. In addition, more than 100 other plant species are susceptible to the organism, yet most of these species suffer only minor damage, limited to leaf spots or twig dieback. This guide provides practical information for arborists on treatments, oak tree health, safety issues, and how to work on host plants without spreading the pathogen.

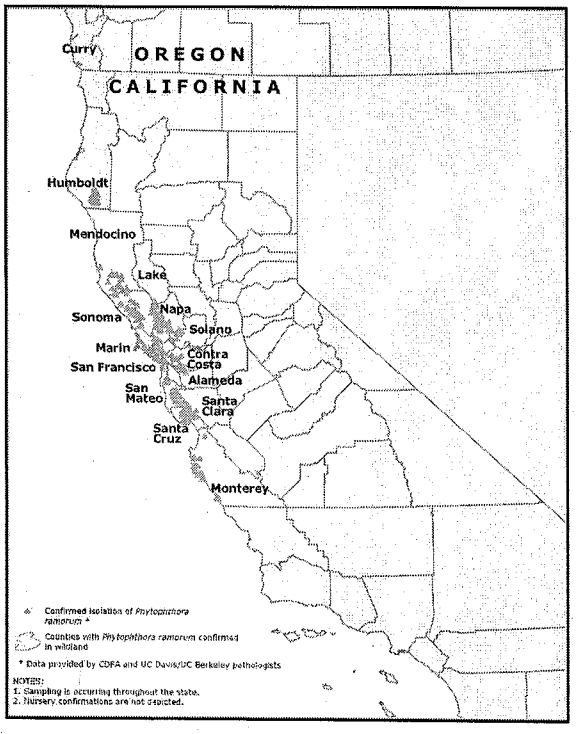
Pathogen biology

Phytophthora ramorum prefers moist environments and mild temperatures. During wet periods, the organism is most active and therefore most likely to start new infections. Therefore, the risk of movement and spread of the organism is greatest in muddy, wet areas and during rainy weather. *P. ramorum* spores can be found in living, dying, or recently dead plants as well as in infested waterways and soil, and may be transported to new areas when infected plant material or infested soil is moved. The pathogen also spreads via wind-blown rain.

Quarantine regulations

Movement and disposal of all plant materials (except seeds and acorns) of *Phytophthora ramorum* host species are regulated by the California Department of Food and Agriculture (CDFA) and the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS). Quarantine regulations have been enacted for Alameda, Contra Costa, Humboldt, Lake, Marin, Solano, Sonoma, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Mendocino and Monterey Counties (see map). There are no restrictions within this 14-county zone, but before moving susceptible plant material out of the quarantine area, you must contact your county agricultural commissioner for a permit. Restrictions and exceptions are provided at the CDFA and APHIS websites. Additionally, all nurseries in CA, OR and WA are under regulation for *P. ramorum*.

While not legally required within the 14 infested counties, thorough cleaning of tools and equipment between jobs and careful safeguarding of susceptible species while transporting is recommended.



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California Oak Mortality Task Force

Cultural treatments

California bay laurels greatly contribute to disease spread to oaks. If oaks dominate the site and are the preferred species, consider removing CA bay laurels whose canopies are within 15 feet of the trunks of valued oaks. CA bay laurels are prolific sprouters so continued maintenance or herbicide stump application may be necessary to eliminate regrowth. Combining bay removal with chemical treatments (see below) may be a viable option if the oaks are very high-value and if the removal of the CA bay laurel will not diminish landscape value. Keep in mind that bays are important for many wildlife species, and should the oaks be lost, bay trees may be the only remaining mature trees. Bay removal is most effective as a preventative treatment.

For isolated infestations (more than 25 miles from known infested areas), a more aggressive, inoculum reduction approach may be worthwhile. In heavily infested areas, inoculum levels are thought to be too high to reduce via removal of infected plant material and duff, but in cases where the pathogen appears to be detected at a very early stage these efforts may prevent pathogen spread. *P. ramorum* sporeloads may be reduced through the removal of known infected trees and neighboring symptomatic hosts and the clean-up of host litter from under the canopy before winter rains enhance spore dispersal. Before implementing any aggressive removal treatments with an aim of reducing innoculum loads, you should first confirm: (1) the presence of *P. ramorum* through laboratory testing; and (2) the distribution and relative abundance of the pathogen in the area.

Chemical treatments

Agri-Fos® (systemic fungicide) and Pentra-Bark™ (surfactant) were approved in 2003 by the California Department of Pesticide Regulation (DPR), under a FIFRA Section 24c Special Local Needs Label, as a treatment for oaks* and tanoaks that are at high risk of contracting *Phytophthora ramorum*. Agri-Fos® is not a universal "cure;" this treatment will not cure trees when *P. ramorum* is already established. Designed primarily for use on high-value trees in yards and gardens, Agri-Fos® is a preventive treatment, and is most effective for inhibiting infection in uninfected trees. Agri-Fos® is systemic; it is translocated through the tree and is thought to enhance the tree's defensive mechanisms. Agri-Fos® requires an estimated 4-6 weeks to be assimilated by the plant before resistance to the pathogen is fully attained.

Agri-Fos® may be used with Pentra-Bark™ penetrant and applied to the trunk and lower limbs (avoiding the leaves) for absorption through the bark or injected into the tree with a drill and an injector. For injection, holes into the wood are drilled approximately every 6" around the circumference of the tree and the material applied under pressure. Refrain from repeatedly drilling and injecting smaller-diameter trees over the course of a multi-year treatment. If applying to the bark, trees with thick accumulations of moss will need to be scraped free of moss prior to application, and surrounding plants will need to be protected from any spray drift. The optimal treatment routine for coast live oaks calls for two applications the first year followed by one application annually thereafter. It is recommended to treat in the fall and then in the spring, or spring then fall the first year. Annual follow up treatments should be only in the fall, avoiding times when trees are not physiologically active. Always apply the material according to the label.

* Treatment recommendations for oak species are based on research trials with coast live oak. Efficacy data for other oak species is not yet available.

Selection of candidate trees for chemical treatment: Since Agri-Fos® must be used on healthy trees and *P. ramorum's* distribution and activity is patchy and somewhat unpredictable, it is difficult to determine which trees are worth treating. Summarized below are some general guidelines. Treatment may be warranted for healthy, high-value oak and tanoak trees within 3 miles of known infested plants (e.g., CA bay laurel, oaks, or others). Conversely, treatment is NOT recommended in areas distant (more than 3 miles) from infested areas.

If symptoms indicate *P. ramorum*, or if the pathogen is CDFA confirmed, consider treating the adjoining high value, non-symptomatic oaks to reduce the likelihood of infection. Tanoaks, however, if they are within 200 yards of any infested plant, should be considered already infested and are not suitable for preventative treatments.

Trees with poor form, poor growth, a spiral growth pattern, an abundance of decay pockets, punk knots, and other malformations on the lower stem will not adequately intake the material and should not be treated. Trees whose vigor has been compromised by other diseases or injuries should not be treated.

Use of insecticides: The use of insecticides to prevent *P. ramorum* infection or to prolong the life of infected trees has not been demonstrated in scientific studies to be beneficial. Insecticides do not prevent pathogen infection and tree death, as the pathogen alone is capable of killing trees.

NOTE: Trees with advanced symptoms (e.g., multiple bleeding areas, extensive beetle attack, numerous *Hypoxylon* fruiting-bodies on the bark surface, and/or a sparse or brown canopy) cannot be saved, although some will survive through natural resistance. Some trees will maintain a green canopy despite displaying many of the above signs and symptoms. Sparse foliage may be due to other factors, such as oak worm.

Tree removal issues

Oak and tanoak trees infected or killed by *P. ramorum* are prone to rapid decay and unpredictable failure. Arborists and other tree care professionals need to be very cautious about climbing *P. ramorum*-infected or killed trees. Infected green trees, as well as trees killed by *P. ramorum* and/or secondary pests, are at increased risk of trunk and limb breakage. Prior to the removal of Sudden Oak Death-infected trees or when working in areas where diseased trees are present, provide a "tailgate safety talk" that covers points discussed below to inform crews of special precautions for working in structurally compromised trees.

A study of the failure potential of coast live oak trees found a strong association between advanced symptoms of *P. ramorum* and branch, scaffold limb, bole, and root crown failures. At least one third of these failures occurred in live trees and stems. The failure rate for infested coast live oak and tanoak was more than 10 times greater than healthy trees. Wood decay was present in almost all failures and was the most consistent and important factor influencing failure potential. Trees with indications of wood decay or deterioration because of beetles and *Hypoxylon* should be removed if they jeopardize emergency access/egress, life, or property. Evaluate structural hazard potential and remove those trees that pose a risk to people, property, pets, livestock, etc. Also consider removing recently killed trees as well as brush and other dead material to lessen the fire hazard potential.

Coast live oak trees are also prone to summer branch failure. Reduced moisture content in infected trees may contribute to branch failure. The wood of *P. ramorum*-infested trees appears to decay rapidly, often resulting in failure within a few months of dying. Diseased trees heavily colonized by bark and ambrosia beetles and the *Hypoxylon* fungus may fail before they have died (while they are still green). Trees that are hazardous to

life, property, roads, campgrounds and other high use areas should be felled without delay. Arborists should pay special attention to Sudden Oak Death trees with internal decay or other structural defects that could increase failure potential or threaten the safety of tree workers.

Cut tree stumps as close to the ground as practical. Stump grinding is not recommended because the equipment may become contaminated by soil and result in pathogen spread when used at another location. The operation of vehicles or heavy equipment in such areas may lead to further disease spread when soil is disturbed and moved around. If at all practical, schedule tree removals from June to October when conditions are warm and dry, and avoid removing diseased trees when moist conditions favor pathogen spread – November to May.

Debris disposal

Proper disposal of infested material contributes toward limiting pathogen spread. In generally-infested areas, leaving *P. ramorum*-infected or killed oak trees on site has not been shown to increase the risk of infection to adjacent trees. Removal from the property is only recommended if it is the first infected tree to be detected in the area, if fire risk is high, or for aesthetic or other reasons. Whenever possible, leave tree debris on site in a safe area where woody debris will not become dislodged, endanger children, contaminate uninfected hosts, or constitute a fire hazard. When infected oaks are cut down and left on site, chip the branches and cut and split the wood. To prevent pathogen spread via muddy boots or equipment, avoid chipping in wet weather. Stack woodpiles in sunny locations to promote rapid drying. Do not leave firewood and chips in an area where they might be transported to another location (e.g. curbside).

Try to dispose of infested materials down slope of, and away from host species. Most dead oaks in rural areas are not easily disposed of due to the steep or rugged terrain or lack of access. Such trees may be felled or left to fail on their own, depending on whether there is a target of value. Leaving infected trees intact on site may benefit wildlife. Dead trees on the edge of oak woodlands adjacent to grass or brush areas (transition zones) can increase fire risk and encourage canopy fires in woodlands. Such trees should be cut up and moved 10 to 30 feet away from the remaining trees, depending on slope. If chipping is not possible, reduce fire hazard by lopping and scattering branches so they lay close to the ground at least 30 feet away from any structure, driveway, roadside, or propane tank (consult your local fire department).

If debris cannot be left on site, infested material should be disposed of at an approved and permitted dump facility. Quarantined materials may move within the quarantine area (in California, the 14 infested counties), but not into non-quarantine areas without approval of the county agricultural commissioner. Do not sell host plants, firewood, wood chip or bark mulch, or compost that originated within the quarantine area without first contacting your local agricultural commissioner's office. As a buyer, check the source of all such material.

Sanitation measures to minimize pathogen spread

As a precaution against spreading the pathogen, clean and disinfect pruning tools after use on confirmed or suspected infested trees or in known infested areas. Sanitize tools before pruning healthy trees or working in pathogen-free areas. Clean chippers and other vehicles of mud, dirt, leaves, organic material, and woody debris before leaving a *P. ramorum* site and before entering a site with susceptible hosts.

Before working

• Inform crews about the arboricultural implications of *P. ramorum* and sanitation practices when they are working in infested areas.

• Provide crews with sanitation kits. (Sanitation kits should contain the following: Chlorine bleach [10/90 mixture bleach to water] or Clorox Clean-up® or Lysol®, scrub brush, metal scraper, boot brush, and plastic gloves).

• Sanitize shoes, pruning gear, and other equipment before working in an area with susceptible species.

While working

• When possible, work on *P. ramorum*-infected and susceptible species during the dry season (June-October) or ask customers to allow flexible scheduling so work may be done during dry spells. When working in wet conditions, keep equipment on paved, graveled, or dry surfaces and avoid mud.

• Work in disease-free areas before proceeding to infested areas.

• If possible, do not collect soil or plant material (wood, brush, leaves, and litter) from host trees in the quarantine area. Within the quarantine area, host material (e.g., wood, bark, brush, chips, leaves, or firewood) from tree removals or pruning of symptomatic or non-symptomatic host plants should remain on site to minimize pathogen spread.

After working

• Use all reasonable methods to sanitize personal gear and crew equipment before leaving a *P. ramorum*-infested site. Scrape, brush, and/or hose off accumulated soil and mud from clothing, gloves, boots, and shoes. Remove mud and plant debris by blowing out or power washing chipper trucks, chippers, bucket trucks, fertilization and soil aeration equipment, cranes, and other vehicles.

• Restrict the movement of soil and leaf litter under and around infected trees as spores may be found there. Contaminated soil, particularly mud, on vehicle tires, boots, shovels, stump grinders, trenchers, etc., may result in pathogen spread if moved to a new, uninfested site. Remove or wash off soil and mud from these items before use at another site. If complete on-site sanitation is not possible, complete the work at a local power wash facility or an isolated area in your equipment yard. Maintaining clean, orderly vehicles and equipment is good business, and prevents pathogen and weed-seed spread.

• Tools used in tree removal/pruning may become contaminated and should be disinfected with Lysol® spray, a 70% or greater solution of alcohol, or a Clorox® solution (1 part Clorox® to 9 parts water or Clorox Clean-up®). Remember that these products are corrosive to metal and fabric. Rinse your gear after sanitation.

Tree care considerations

Creating favorable growing conditions, avoiding disturbances to the root zone, avoiding unnecessary pruning, pruning properly, avoiding harmful landscaping and gardening practices, and mitigating environmental stress, is prudent for the general health of oaks. However, these efforts may not prevent Sudden Oak Death. This disease is caused by a virulent pathogen, capable of killing healthy trees.

Although native oaks are well-adapted to their local environment, various climatic events, irrigation, and disturbances within the root zone can cause stress and increase vulnerability to pest attack. Drought, unusually wet soil conditions, regular and frequent irrigation, root loss, poor drainage, soil compaction, and pavement are common factors causing stress. Maintaining or restoring favorable growing conditions and avoiding disturbances are the best ways to maintain tree health.

Pruning: Pruning of host plants should be avoided or minimized as wounds may serve as entry sites for this disease and attract bark beetles. Also, arboricultural tools and equipment may transport infectious spores to uncontaminated sites. Prune only as necessary and avoid excessive foliage removal. Removing more than 20% of a mature oak's foliage can impair its health. If possible, avoid pruning in winter and spring months, when there is increased risk of pathogen spread. Work with clients to schedule pruning of *P. ramorum*-infected trees or shrubs, or host species during the dry months of June through October. Strictly follow arboricultural pruning standards (ISA Pruning Standards and ANSI A300). If pruning of major limbs (over 4 inches diameter) or stems is necessary, it may be helpful to remove bay branches from the proximity (within 8 feet).

Preliminary research also suggests that amending the top organic layer of soil near susceptible oaks with a commercial grade compost may help prevent *P. ramorum* from spreading through soil splash.

References and resources

• Distribution of Sudden Oak Death: kellylab.berkeley.edu/SODmonitoring/OakMapper.htm

• Treatment recommendations: Forest Pathology and Mycology Laboratory, Matteo Garbelotto, UC-Berkeley, http://www.cnr.berkeley.edu/garbelotto/english/treatment.php

- Garbelotto, M. (2007) Phosphite treatments to control sudden oak death in California oaks and tanoaks. Arborist News, August: 32-33. http://www.cnr.berkeley.edu/garbelotto/downloads/ArbNews2007.pdf
- Garbelotto, M., Schmidt, D., & Harnik, Y. (2007) Phosphite injections and bark application of phosphite + Pentrabark control Sudden Oak Death in Coast Live Oak. Arboriculture & Urban Forestry 33(5): 309-317. http://www.cnr.berkeley.edu/garbelotto/downloads/AandUF2007.pdf

• Failure potential in coast live oak: Phytosphere Research, Ted Swiecki, http://phytosphere.com/publications/Phytophthora_case-control2006-2007.htm

• Drying infested wood to destroy the pathogen: ceres.ca.gov/foreststeward/html/treenotes.html

• California Department of Food & Agriculture (CDFA): www.cdfa.ca.gov/index.htm

• USDA, Animal & Plant Health Inspection Service (APHIS): http://www.aphis.usda.gov/plant_health/plant_pest_info/

• General information of Sudden Oak Death: The California Oak Mortality Task Force (COMTF), www.suddenoakdeath.org

NOTE: The recommendations above are based on the best science and professional judgment currently available. Studies conducted on the use of Agri-Fos® and Pentra-BarkTM against *P. ramorum* are relatively new and ongoing; therefore recommendations are subject to change. Studies on insecticide effectiveness and cultural treatments are also limited. Reference herein to these specific commercial products does not constitute or imply its favoring by the COMTF. Before choosing to use any chemical application, always consider potentially adverse environmental impacts.

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In this Guideline:

Sudden oak death is a disease of oak trees caused by an invasive plant pathogen, *Phytophthora ramorum*. It currently occurs in coastal California counties from Monterey to Humboldt and in a small portion of southwest Oregon. It is estimated to have killed more than 1 million oak and tanoak trees during the last decade. In addition, more than 100 other plant species are susceptible to the pathogen, but most suffer only minor damage limited to leaf spots or twig dieback.

Although Sudden oak death is a forest disease, it is common in urban-wildland interface areas—places where development meets or intermingles with undeveloped wildland—and can present many challenges for residential landscapes. Diagnosis of infected trees and proper disposal of contaminated wood and other material are essential to limiting the spread of the disease. Management options include treatment with phosphonate compounds and selective plant removal.

Because *P. ramorum* can be spread by moving infested soil and plant materials, state and federal regulations are in place to control the potential spread of the pathogen to uninfested areas. The California Department of Food and Agriculture (CDFA) and the U.S. Department of Agriculture Animal and Plant Health Inspection Service (USDA–APHIS) regulates movement of any known host species. A quarantine is in place for the infested counties. Before moving regulated plant material out of quarantined areas, you must contact your agricultural commissioner for a permit.

LIFE CYCLE/BIOLOGY OF PATHOGEN

Phytophthora species are funguslike organisms, related to algae, which occur worldwide. They are water loving and produce plentiful spores in moist or humid conditions. Most known *Phytophthora* species are soil-dwelling root pathogens; however, *P. ramorum* acts primarily as a leaf pathogen. In California, it thrives in the coastal tanoak/redwood forests and oak woodlands within the fog belt. Nurseries outside of these cool, moist areas often create microclimates that mimic an environment supportive of *P. ramorum* and allow it to grow and spread far from the coast.

While most nonoak hosts are not killed by the disease, they do play a key role in the spread of *P. ramorum*, acting as a breeding ground for inoculum that can spread through water, wind-driven rain, plant material, or human activity. Oaks are considered terminal hosts, since the pathogen does not readily spread from intact bark cankers; they become infected only when exposed to spores produced on the leaves and twigs of neighboring plants.

Research in California forests has shown that the greatest predictor of *P. ramorum* canker on oak is the presence of California bay laurel (*Umbellularia californica*). Pathologists believe *P. ramorum* drips or is blown down onto oak trunks from neighboring bay leaves when it rains. Once on the oak trunk, *P. ramorum* uses natural openings in the bark to colonize the bark tissues, killing cells and clogging water and nutrient transport vessels.

IDENTIFICATION

Infections caused by *P. ramorum* must be confirmed in the laboratory utilizing either culture techniques or DNA analysis for detection of pathogen DNA. They cannot be identified on field symptoms alone. However, infected plants typically are found near other infected plants, so when oaks or other hosts with characteristic symptoms of Sudden oak death are found within forests or woodlands where the disease already has been confirmed, these plants should be suspected to be infected with *P. ramorum*. Oaks growing farther from infested forests are not as likely to be infected unless infected material or nursery stock has been brought to the area. Check online mapping resources for the most current data on pathogen distribution.

There are two categories of hosts for *P. ramorum*—trunk hosts and foliar hosts. Trunk hosts, such as tanoaks and oaks, get infections in their bark. These trunk infections often are fatal. Other organisms often attack diseased oak and tanoak trees once *P. ramorum* has weakened them. These include ambrosia beetles (*Monarthrum scutellare* and *M. dentiger*), bark beetles (*Pseudopityophthorus pubipennis*), and a sapwood decay fungus (*Annulohypoxylon thouarsianum*). Though these attacks are secondary to the original *P. ramorum* infection, they act to further weaken the trunk and can hasten the tree's death.

On foliar hosts—such as California bay laurel, rhododendron, or camellia—symptoms can range from leaf spots to twig dieback, but these hosts rarely die from the infection. Rather than Sudden oak death, a *P. ramorum* infection on these hosts is known as Ramorum blight. Symptoms of *P. ramorum* infection on some key hosts are detailed below.

Oaks (Quercus species)—Coast Live Oak, Canyon Live Oak, California Black Oak, and Shreve's Oak

The oak genus is divided into three subgenera, or groups: white, red, and golden/intermediate. Oaks from the white group—valley oak, Garry oak, and blue oak along with some scrub oak species—are not thought to be susceptible to Sudden oak death, although other oaks do get the disease.

Susceptible trees in the red oak group (coast live oak, California black oak, and Shreve's oak) and intermediate group (canyon live oak) develop a bark canker when infected. External symptoms of canker development can include the bleeding of a thick, sticky sap. It typically smells like the inside of a wine barrel and is a deep burgundy but can vary in color from nearly black to an amber-orange. Recent rains can cause the sap to run, often producing large stains on the surrounding bark. Only larger trees—those that are more than 4 inches in diameter at chest height—show symptoms; infections of smaller saplings are extremely rare. Mosses and lichens growing on the tree trunk die if the sap comes in contact with them. Their death might be the only indication a tree is bleeding.

The bleeding is the external manifestation of an underlying, diseased area of the tree, or canker. Removing the surface bark will reveal discolored, brown tissue, normally separated from healthy bark by a distinct, black zone line, although this line can be somewhat indistinct during periods of active pathogen expansion, typically in the spring. This zone line represents the active front of the infection. Cankers usually develop 3 to 6 feet from the ground, although they can be as high as 12 feet or greater; they can be as low as soil level, but they are not thought to extend below the soil line. Bleeding sap initially appears on intact bark, without any obvious holes or wounds, although in later stages of the disease the bark might split.

P. ramorum infections on oaks originally were called "Sudden oak death" because of the rapid (2- to 4-week) browning of leaves without an apparent, prolonged period of visible decline. The foliage might appear healthy until shortly before it turns brown, or the leaves might turn olive green, pale green, or yellow green for several weeks to several months before browning. Infected coast live oaks also might lose leaves before they die. There are no other symptoms on leaves or small twigs of most *Quercus* species, although canyon live oaks, *Q. chrysolepis*, might have lesions on smaller twigs. While this browning of leaves can appear suddenly, it usually occurs after an extended period of disease, perhaps more than 2 years from the onset of a *P. ramorum* infection of the trunk.

Tanoak (Notholithocarpus densiflorus)

Tanoak is highly susceptible to *P. ramorum*, and the disease can infect and kill all sizes and ages—seedlings, saplings, and mature trees. *P. ramorum* infects trunks, branches, twigs, leaves, and leaf petioles (the slender stems that support leaves). Experiments on tanoak trees revealed they could be infected without showing cankers or bleeding symptoms, making diagnosis difficult. When visible, trunk cankers are similar to those of the red oak group. Death can occur with a sudden browning of the leaves, as with the red oaks, or over time with gradual leaf loss. *P. ramorum* infection in twigs can lead to shoot tip dieback and wilting. Shoot tip wilting, or flagging, can be useful in identifying trees that are infected but not showing bleeding symptoms. Tanoaks, unlike *Quercus* species, can produce spores from infected twigs, which can then be dispersed both within the tree and to neighboring susceptible plants, potentially causing new infections. Infected trees with brown foliage are effectively dead, although there might be some sprouting from the tree bases. Many of these new shoots are likely to become infected within a growing season.

Nonoak Hosts

Just a few foliar hosts, listed below, support pathogen populations large enough to spread *P. ramorum* to susceptible oaks and tanoaks. For a more complete list and description of nonoak hosts and symptoms, see *Sudden oak death and associated diseases caused by* Phytophthora ramorum (Davidson et al. 2003) and *Nursery Guide for Diseases of* Phytophthora ramorum *on Ornamentals: Diagnosis and Management* (Tjosvold et al. 2005) in References. Please note that there are many potential causes of leaf spots on each of these hosts, so these symptoms descriptions should be used only as a guideline.

California bay laurel (*U. californica*). On California bay laurel, *P. ramorum* causes leaf spots, usually brown tips surrounded by a halo of yellow. Lesions typically are found where water collects on the leaf. This is generally its tip, although a leaf spot can develop elsewhere where water rests on the surface. Bay laurel are not thought to die from *P. ramorum* infection, but these trees are a major source of inoculum for the pathogen and appear to play an important role in spreading disease to other plants in California.

Rhododendron (*Rhododendron* species). Leaf spots are the main symptom on rhododendrons, although more severe effects have been noted in some cases. Lesions penetrate through the plant tissue so that spots are identical both on the top and bottom of the leaf. They are often triangular and extend along the leaf midvein, but they can appear anywhere water collects on the leaf surface such as along edges, near the petiole, and at the leaf tip. Leaf spots have diffuse margins and might appear water soaked. In severe cases, twigs, stems, or entire plants can die.

Camellia (*Camellia* species). Camellia symptoms usually are limited to leaf spots, which can vary in size from 1/4 inch in diameter to covering nearly half the leaf, depending on environmental conditions. Lesions usually are on the leaf tip or leaf edge, and diffuse margins or thick black zone lines can surround them. Plants will drop their infected leaves, and the lower part of the plant can defoliate. Occasionally flowers or buds will be affected. Tip dieback or small branch cankers have not been observed on *Camellia* species.

DIAGNOSIS

Many common maladies other than *P. ramorum* infections can cause damage that resembles Sudden oak death. Other possible causes include boring insects, oak root rot (*Armillaria mellea*), root and crown rots (e.g., *P. cinnamomi*), physical injury, wetwood bacteria, and inappropriate cultural practices such as summer irrigation. (See *Pests of Landscape Trees and Shrubs* in References.) Figures 10 (for trees growing in wild areas or landscapes), 11 (for plants that just came from a nursery), and 12 (for trees that are dead) provide assistance in determining whether *P. ramorum* is a likely cause of the symptoms on your plants.

Once you have determined that *P. ramorum* is a probable cause of the symptoms you have observed, the final step in getting a confirmed diagnosis is to submit the symptomatic plant material to a laboratory for testing. Even if you are concerned about the health of an oak, because the pathogen is more readily isolated from leaves than trunks, it is better to focus sampling efforts on foliar hosts such as bay trees that surround your oak. Following are two methods for collecting and submitting a sample for a more thorough *P. ramorum* diagnosis.

Foliar Sampling

Foliar sampling involves collecting about 10 symptomatic leaves from a foliar host (typically bay laurel) and submitting them for analysis. It is perhaps the easiest and most reliable way to determine if *P. ramorum* is present at a given location. Because infestation levels vary tremendously throughout the state, it is best to contact your local Cooperative Extension or County Agricultural Commissioner's office for information on how sampling is being handled in your area.

Bark Sampling

While bark sampling is the only way to directly confirm disease on an infected oak, this procedure is invasive, it requires special equipment from the laboratory, and improper sampling techniques will greatly influence results. If you do decide to collect a bark sample, you must request sampling materials in advance from the laboratory. It is recommended you work with a trained sampler.

DAMAGE

Phytophthora ramorum affects different species in different ways. It can be lethal to trunk hosts and madrone (*Arbutus menziesii*) saplings, while it might cause only a minor leaf or needle disease for the numerous foliar hosts. Depending on a number of factors, some trees might never become infected, some might become infected and survive for various lengths of time, and others might become infected and die quickly. In a few, rare cases, trees have recovered on their own.

Because Sudden oak death is a relatively new disease in California, it will take time to determine how likely different outcomes are for different tree species. Initial observations tell us that once infected, tanoak has a high probability of *P. ramorum* killing it, but some trees will survive. Coast live oaks appear to have a lower mortality rate than tanoaks, although the disease has killed many of them. There is little mortality information on California black oak at this time, so it is difficult to predict how this species will fare.

Trees growing in a mixed woodland or forest environment seem more likely to become infected by *P. ramorum,* as it spreads naturally in forest settings along coastal California. Oaks in residential landscapes seem less likely to be infected with Sudden oak death, because they usually are not growing as close to foliar hosts such as California bay laurel. An exception would be when horticultural hosts such as rhododendrons and camellias are growing close to oak trunks.

MANAGEMENT

Once Sudden oak death infects oak trees, there is no known way to cure them. Therefore, most of the management practices discussed below are directed at preventing the spread of the disease to new plants or areas and protecting susceptible trees before they are infected.

Inspecting Nursery Plants Before Making a Purchase

Many common horticultural plants are hosts for *P. ramorum*, and nurseries in California, other states, and other countries have found the pathogen on their plants. Plants are shipped all across the country, but they are strictly regulated. All *P. ramorum* host plants in California's regulated counties must be inspected and approved prior to shipment out of the regulated area, although sales within the regulated zone of 14 counties are not. In either case, carefully inspect the leaves of host plants for symptoms before making a purchase. Nurseries often use general fungicides that can mask *P. ramorum* symptoms, and some plants might have asymptomatic or latent infections that might not be visible at the time of purchase. Even if you do not see signs of infections when you make a purchase, consider quarantining the new plant in moist area of your yard for up to 8 weeks to see if symptoms manifest before you transplant it. You might want to refrain from planting any of these horticultural hosts near susceptible oaks in your yard.

Removing Infected Oaks

A tree with Sudden oak death needs to be considered and treated differently than a tree without the disease, but the disease alone is not justification for removal. In some cases, oak trees infected with the disease can remain relatively healthy for some time. Since data indicate nonoak foliar hosts actually spread the pathogen, removing infected oak trees probably will have little or no impact on local disease levels and spread. However, an important consideration with respect to any tree is whether it presents a hazard to life or property. All trees present some hazard, depending on the tree's structural integrity and its potential to do harm should it die or portions of it break off. Preliminary research has shown that trees *P. ramorum* has infected or killed are prone to rapid decay and unpredictable failure. Green infected trees and trees already dead from *P. ramorum* and/or secondary pests are at an increased risk of trunk and limb breakage.

The decision to remove a hazardous tree ultimately lies with the property owner. In order to get an objective assessment of hazardous conditions, contact a certified arborist or other qualified professional. While a dead tree has an increased risk of causing damage, consider leaving it standing if there is not a risk to life or property, such as when the tree is in a natural area. Standing dead trees provide important wildlife habitat, and after they fall and decay, they are a source of nutrients to be recycled into the soil.

Always consult regulatory officials regarding local tree ordinances before deciding to remove trees. Experienced tree service technicians should conduct tree felling, as infected trees might have an abundance of structural wood decay. If there is an acute emergency, contact your city arborist or local fire or police department.

Removing Nonoak Host Trees

Large-scale removal of nonoak host plants is not a recommended way to prevent disease spread at a residential level. However, selective removal and/or pruning of these foliar hosts when they are in close proximity to uninfected, susceptible oaks might be helpful in preventing particular oaks from becoming infected, especially if there are few other disease hosts nearby. For more information, see *Sudden Oak Death and Residential Oak Care: Protecting Trees in Advance of Local Disease Establishment* (Lee, Valachovic, and Garbelotto 2010) in References.

Disposing of Plant Debris

Since *P. ramorum* has been present in many areas of coastal California for a decade or longer, complete eradication is impossible. However, the disease is not uniformly distributed, and there are still many areas that remain uninfested. If infested plant materials are moved, they inadvertently can transfer the pathogen to uninfested areas. Disposal of infested material is extremely important, because branches, twigs, and leaves from California bay laurel, rhododendron, and other host plants can harbor *P. ramorum*, even after they are removed from the plant. In infested areas, the best option is to leave infested material on site, chipping the small material for use as ground cover and using larger pieces for firewood. Since inoculum levels already are thought to be high in these infested areas, leaving the additional inoculum from the infested plant material on site will not significantly worsen local disease conditions. Composting also can successfully kill the pathogen, but the compost must reach temperatures that probably are not possible or practical in a home-composting site.

Removing plant debris from the property is recommended only if it is the first infected tree detected in the area or if fire risk is high. If infected wood is removed from your property, make sure it is utilized or disposed of in a way that does not spread the disease. Avoid leaving wood next to roads where it could be picked up and transported off site by unauthorized parties. Regulations prohibit the movement of host plants and plant parts out of the quarantined area. If you have infected trees cut down, make sure the wood and other tree parts are not moved outside of the quarantine area.

Sanitation Measures to Minimize Pathogen Spread
As a precaution against spreading the pathogen, clean and disinfect pruning tools after use on confirmed or suspected infested trees or in known infested areas. Sanitize pruning tools before pruning healthy trees or working in a pathogen-free area. Clean vehicles and shoes of mud, dirt, leaves, and woody debris before leaving a *P. ramorum*-infested site and before entering a site with susceptible hosts.

Replanting After Removing an Infected Tree
If you want to replant, it is important to choose a tree that will suit your needs and adapt well to the site. There are many resources available that can guide you in making the right choice. Check to see if there are any local ordinances or guidelines that govern tree replacement or planting.

Resistance to *P. ramorum* in oak trees is just beginning to be explored. Resistant planting stock is not available at this time nor is it known if it ever will be available. Coast live oaks do not seem to be infected by *P. ramorum* until they reach about 4 inches in diameter, so small, new trees should be immune for a number of years, and high value trees can be preventatively treated once they reach a susceptible size. (See Preventative Phosphonate Treatments below.) Species in the white oak group (e.g., valley oak, Garry oak, and blue oak) are not susceptible to *P. ramorum*. If you have space for replanting many trees, consider replanting the lost species in combination with other trees that do not get the disease. Then, if some trees succumb to *P. ramorum* there still will be others that survive.

Preventative Phosphonate Treatments
One phosphonate fungicide, Agri-Fos, is registered as a preventative treatment for *P. ramorum* for use on individual, high-value tanoak and oak trees. Treatment is not recommended in areas where infested plants are not already present. This treatment is not a cure, but it can help protect trees from infection and suppress disease progression in very early infections. The phosphonate compound can be injected or mixed with a surfactant and sprayed on the trunk for absorption through the bark. Booster treatments need to be made every 1 to 2 years.

Since the treatment must be made to healthy trees and the pathogen's distribution and activity is patchy and somewhat unpredictable, it is difficult to determine which trees need treatment. Generally, you should consider treating healthy, high-value oak or tanoak trees within 150 feet of other infested plants. You also might want to treat healthy, high-value oaks or tanoaks if they are surrounded by healthy California bay laurel and there are known infections within 150 to 1,000 feet. For more information, see *Sudden Oak Death and Residential Oak Care: Protecting Trees in Advance of Local Disease Establishment* (Lee, Valachovic, and Garbelotto 2010) in References.

Insecticides
Using insecticides to treat or prevent *P. ramorum* infections provides no control and is not justified. However, treating individual, high-value landscape trees displaying early bleeding symptoms of Sudden oak death might be justified to control damage from secondary bark beetle attacks. If using an insecticide, apply it only if the disease is not at an advanced stage and with the realization it might prolong the life of the tree only for a relatively short time. For more information, see *Pest Notes: Bark Beetles* in References.

WARNING ON THE USE OF CHEMICALS

ONLINE RESOURCES
California Oak Mortality Task Force

OakMapper

UC Berkeley Forest Pathology and Mycology Laboratory

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