CALIFORNIA OAK MORTALITY TASK FORCE REPORT
APRIL 2022

Editor's note. In this issue we continue our 2021 review of *Phytophthora ramorum* status in California wildlands and nurseries, and feature drought-related damage on tanoak caused by endophytic fungi or "latent pathogens". We encourage you to follow the links to more photographs, tables, and other information.

MONITORING – CALIFORNIA WILDLANDS

In 2021, California aerial survey found decreased tree mortality attributed to sudden oak death (SOD, *Phytophthora ramorum*): an estimated 97,000 dead trees across 16,000 acres, compared to ~885,000 dead trees across 92,000 acres in 2019 (see Figures 1 & 2). There were no flights in 2020 due to COVID precautions. The greatest amount of tree mortality was observed in Humboldt and Sonoma Counties. The declining trend in SOD tree mortality is understood to be driven by climatic conditions, namely a wet year in 2017, followed by a run of dry years.

Substantial tanoak mortality caused by drought stress and other fungi was also recorded both in SOD infested areas and beyond. For more on the cause of that tanoak mortality see page 7 of this report.

A California 2021 aerial survey of tree mortality report and a synopsis infographic are available from the U.S. Forest Service, Pacific Southwest Region, or contact Jeffrey Moore, jeffrey.moore@usda.gov.

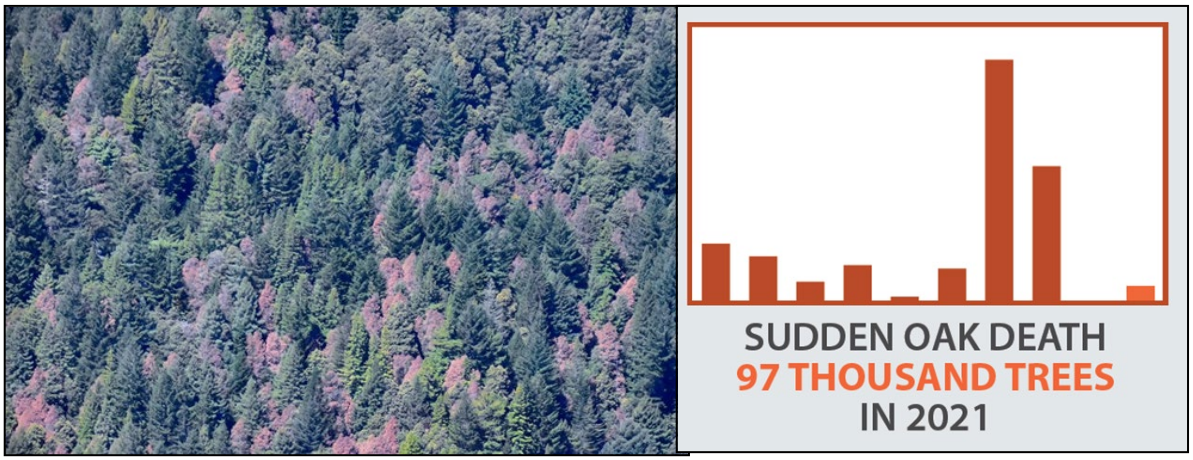


Figure 1. Left. Sudden oak death of tanoak in Sonoma County in 2021. Figure 2. Right. Trend of number of wildland trees that died due to *P. ramorum* infection in California from 2012-2021.
Credit: USFS, PSW Region, Forest Health Protection, Aerial Detection Survey.

MONITORING – CALIFORNIA SOD BLITZ. CALL FOR VOLUNTEERS

SOD Blitz 2022 is seeking volunteers to survey their communities for *P. ramorum*. Starting in April, more than a dozen communities from San Luis Obispo north to Del Norte County are participating in this annual citizen-science *P. ramorum* survey. The schedule and training materials are now available. No previous experience is necessary. Sampling protocols are COVID safe. Volunteer-collected samples will be analyzed by Matteo Garbelotto's Forest

Pathology and Mycology Laboratory, UC Berkeley. For more information contact Doug Schmidt, dschmidt@berkeley.edu.

NURSERIES AND MANAGED LANDSCAPES

2021 USDA APHIS PPQ *P. ramorum* program summary. In 2021, the USDA APHIS, Plant Protection and Quarantine (PPQ), *P. ramorum* program supported compliance activities, diagnostics, and surveys in 22 states. *P. ramorum* was detected at 17 different establishments: eight were new and nine were previously positive. Confirmed positive samples were collected at interstate shipping nurseries, at intrastate shipping nurseries including big box stores, and at a large managed landscape. *Viburnum* was the species with the most *P. ramorum* confirmations in 2021 (Table 1). A complete report with several tables is available HERE.

Table 1: Samples confirmed positive by APHIS for *P. ramorum* in 2021 by sample type.

Sample Type	Quantity	Percent
Arbutus	2	0.67
Camellia	5	1.67
Gaultheria	1	0.33
Leucothoe	1	0.33
Loropetalum	12	4.00
Pieris	17	5.67
Rhododendron	97	32.33
Rhododendron [azalea]	9	3.00
Soil	7	2.33
Viburnum	145	48.33
Water (Bait)	4	1.33
Grand Total	**300**	

California Department of Food and Agriculture (CDFA) *P. ramorum* program update. Spring compliance inspections at previously positive nurseries and a trace-back inspection are underway. Eight California nurseries that were previously positive for *P. ramorum* are currently undergoing their first biannual inspection for 2022 in compliance with federal regulations.

One nursery that had 145 positive *Viburnum tinus* plants detected in December 2021 is now undergoing a trace-back inspection after a positive trace-forward plant was detected at a nursery in another state. Annual inspections at other nurseries and establishments with compliance agreements in quarantined counties are also being conducted. For more information contact Carolyn Lambert, Carolyn.Lambert@cdfa.ca.gov.

Oregon Department of Agriculture *P. ramorum* Nursery program update. Currently, there are five nurseries participating in the Oregon *P. ramorum* Nursery program. All nurseries are interstate shippers under federal compliance agreements (7 CFR 301.92). They are in Washington (2), Columbia (1), and Marion (2) counties. One of the two nurseries in Washington County was newly added to the program in March 2022.

The Columbia County nursery which tested positive for *P. ramorum* during the fall 2021 compliance inspection has undergone four delimitation sampling events throughout the winter. This resulted in the detection of an additional 30 positive foliar samples. The nursery has destroyed all material within the destruction and quarantine zones. Four additional water samples were collected from ditches, sprinklers, and sprinkler lines during the delimitation work. All water samples tested negative for *P. ramorum*. There are 22 inconclusive samples from the third delimitation and two from the fourth delimitation that are awaiting lab results. The nursery in Marion County that was under investigation because of a traceback from the fall 2021 compliance agreement inspection tested negative for *P. ramorum*.

The Oregon Department of Agriculture was notified in February that five nurseries would be impacted from a trace-forward from another state. Inspectors followed the trace-forward protocol and detected no *P. ramorum* at four of the nurseries. One nursery in Washington County was found to have one positive foliar sample, so the nursery has been added to the program.

Compliance inspections for the 2022 spring season began on March 22. To be released from the program, nurseries must have 6 consecutive negative results from compliance inspections over three years. No nurseries will be eligible for release from the program this spring. For more information contact Kaitlin Gerber, kaitlin.gerber@oda.oregon.gov.

Washington State Department of Agriculture (WSDA) *P. ramorum* program update.
In February, WSDA conducted two trace-forward investigations on plants that shipped from positive out-of-state nurseries. Inspectors followed up on high-risk genera at five receiving nurseries in Washington. Thirteen samples were collected at four locations and all samples tested negative for *P. ramorum*. In early May, a certification survey will be conducted at Washington's only regulated interstate shipping nursery. For more information contact Scott Brooks at SBrooks@agr.wa.gov.

RESEARCH

Carleson, N.C.; Press, C.M. and Grünwald, N.J. 2022. High-quality, phased genomes of *Phytophthora ramorum* clonal lineages NA1 and EU1. Molecular Plant-Microbe Interactions. MPMI-11. https://doi.org/10.1094/MPMI-11-21-0264-A.

Currently, two distinct *P. ramorum* clonal lineages, NA1 and EU1, cause disease in Oregon and California forests. Carleson and others report on two high-quality genomes of individuals belonging to both clonal lineages using PacBio long-read sequencing technology. The NA1 strain PR-102, originally isolated from coast live oak in California, is the current reference genome and was previously sequenced independently using either Sanger (*P. ramorum* v1) or PacBio (*P. ramorum* v2) technology. The EU1 strain PR-15-019 was obtained from tanoak in Oregon. These new genomes have a total size of 57.5 Mb, with a contig N50 length of approximately 3.5-3.6 Mb and encode approximately 15,300 predicted protein-coding genes. Genomes were assembled into 27 and 28 scaffolds with 95% BUSCO scores and are considerably improved relative to the current JGI reference genome with 2,575 scaffolds or the PacBio genome with 1,512 scaffolds and has equally high completeness of gene calls. The authors state these, "high-quality genomes provide a valuable resource for studying the genetics, evolution, and adaptation of these two clonal lineages."

Daniels, H.; Navarro, S.M. and LeBoldus, J.M. 2022. Local eradication of *Phytophthora ramorum* is effective on both NA1 and EU1 lineages in Oregon tanoak forests. Plant Disease. https://doi.org/10.1094/PDIS-07-21-1588-RE. (Early View.)

Sudden Oak Death (SOD), caused by the oomycete *Phytophthora ramorum*, has been actively managed in Oregon since its discovery there in 2001. SOD is a devastating disease infecting an ecologically and culturally important tree species in southwest Oregon. Initially infested with the NA1 lineage, the more virulent EU1 lineage was discovered in 2015. Management has adapted over time in response to experimental findings and administrative limitations. Current management practices present an opportunity to compare the efficacy of treatment on these lineages by analyzing *P. ramorum* inoculum at untreated and treated sites. Current treatment includes herbicide treatment on host stems followed by felling, piling, and burning on-site. Infested sites were visited between 2018 and 2020 (n = 88), where understory vegetation and soil was collected. Generalized linear modeling demonstrated treatment had a significant impact on *P. ramorum* prevalence from vegetation samples, with an average of 33% (± 10%) fewer positive samples at treated sites. Linear mixed-effects modeling of a subpopulation of EU1 sites visited before and after treatment showed a similar effect of treatment, with a 43% (± 15%) reduction in *P. ramorum* prevalence. Prevalence of *P. ramorum* in soil was not affected by treatment in either analysis. A third analysis taking into consideration recent wildfire incursion into infested areas revealed that wildfire alone is insufficient to reduce prevalence of *P. ramorum*. These results strongly suggest that management is successfully reducing *P. ramorum* inoculum found on understory vegetation, and that treatment remains necessary to reduce the spread of this major forest pathogen.

Enright, D.J.; Frangioso, K.M.; Isobe, K.; Rizzo, D.M. and Glassman, S.I. 2022. Mega-fire in redwood tanoak forest reduces bacterial and fungal richness and selects for pyrophilous taxa that are phylogenetically conserved. Molecular Ecology. (Early view).

Mega-fires of unprecedented size, intensity, and socio-economic impacts have surged globally due to climate change, fire suppression, and development. Soil microbiomes are critical for post-fire plant regeneration and nutrient cycling, yet how mega-fires impact the soil microbiome remains unclear. We had a serendipitous opportunity to obtain pre- and post-fire soils from the same sampling locations after the 2016 Soberanes mega-fire burned with high severity

throughout several of our established redwood-tanoak plots. This makes our study the first to examine microbial fire response in redwood-tanoak forests. We re-sampled soils immediately post-fire from two burned plots and one unburned plot to elucidate the effect of mega-fire on soil microbiomes. We used Illumina MiSeq sequencing of 16S and ITS1 to determine that bacterial and fungal richness were reduced by 38-70% in burned plots, with richness unchanged in the unburned plot. Fire altered composition by 27% for bacteria and 24% for fungi, whereas the unburned plots experienced no change in fungal and negligible change in bacterial composition. We observed pyrophilous taxa that positively responded to fire were phylogenetically conserved, suggesting shared evolutionary traits. For bacteria, fire selected for increased Firmicutes and Actinobacteria. For fungi, fire selected for the Ascomycota classes Pezizomycetes and Eurotiomycetes and for a Basidiomycota class of heat-resistant Geminibasidiomycete yeasts. We build from Grime's Competitor-Stress tolerator-Ruderal (C-S-R) framework and its recent microbial applications to show how our results might fit into a trait-based conceptual model to help predict generalizable microbial responses to fire.

Kozanitas, M.; Metz, M.R.; Osmundson, T.W.; Serrano, M.S. and Garbelotto, M. 2022. The epidemiology of sudden oak death disease caused by *Phytophthora ramorum* in a mixed bay laurel-oak woodland provides important clues for disease management. Pathogens. 11(2): 250. https://doi.org/10.3390/pathogens11020250.

Epidemiological models are important for the understanding of disease progression in plants and for the design of control strategies. *Phytophthora ramorum*, the pathogen responsible for the disease known as Sudden Oak Death, causes lethal infection on several oaks but relies on California bay laurels for transmission. Here, repeated surveys of bay laurels and oaks indicated that bay laurel disease incidence was positively correlated with rainfall, bay laurel density, and an eastern aspect, and negatively correlated with bay laurel basal area. Oak infection only occurred in years when rainfall was higher than the 30-year average, and although infection rates were greater among larger trees, mortality was greater among smaller trees. Additionally, larger oaks closer to infected bay laurels exhibited greater infection rates. Disease incidence differed among sites, and only a fraction of bay laurels were disease superspreaders, while even fewer individuals were refugial trees harboring active infections during dry periods. Based on this study, reducing bay laurel density in denser stands and the number of superspreaders or refugial trees in less dense stands may reduce disease incidence. However, the selective removal of bay laurel trees 0–10 m from oaks is likely to be more effective in preventing infection of specific oaks.

Peterson, E.K.; Sondreli, K.L.; Reeser, P.; Navarro, S.M.; Nichols, C.; Wiese, R.; Fieland, V.; Grünwald, N.J. and LeBoldus, J.M. 2022. First report of the NA2 clonal lineage of the sudden oak death pathogen, *Phytophthora ramorum*, infecting tanoak in Oregon forests. Plant Disease. https://doi.org/10.1094/PDIS-10-21-2152-PDN. (Partial summary, Early view).

In the spring of 2021, tanoak (*Notholithocarpus densiflorus* Manos, Cannon & Oh) displaying symptoms consistent with sudden oak death (SOD) were detected north of Port Orford (Curry County, Oregon). Symptoms were canopy dieback and blackened petiole and stem lesions on tanoak sprouts. The pathogen isolated on PAR (CMA plus 200 ml/L ampicillin, 10 mg/L rifamycin, 66.7 mg/L PCNB) selective media was determined to be *P. ramorum* based on characteristic morphology of hyphae, sporangia, and chlamydospores. Positive identification as

P. ramorum was obtained with a lineage-specific LAMP assay targeting an NA2 orphan gene, indicating the presence of the NA2 lineage. Peterson and colleagues completed Koch's postulates using potted tanoaks, wound-inoculated at the midpoint of 1-year old stems with either hyphal plugs or non-colonized agar (n=4 per treatment). This is the first detection of the NA2 lineage causing disease in forests worldwide. The outbreak was found on private and public lands in forests typical to the SOD outbreak in Oregon (mixed conifer and tanoak), and was 33 km north of the closest known *P. ramorum* infestation. Follow-up ground surveys on adjacent lands have identified over 100 *P. ramorum*-positive tanoak trees, from which additional NA2 isolates have been recovered from bole cankers. NA2 is thought to be more aggressive than the NA1 lineage, which has been present in Curry County since the mid-1990s. Eradication of the NA2 lineage is being pursued to slow its further spread and prevent overlap with existing NA1 and EU1 populations. The repeated introductions of novel lineages into the western United States native plant communities highlights the vulnerability of this region to *Phytophthora* establishment, justifying continued monitoring for *P. ramorum* in nurseries and forests.

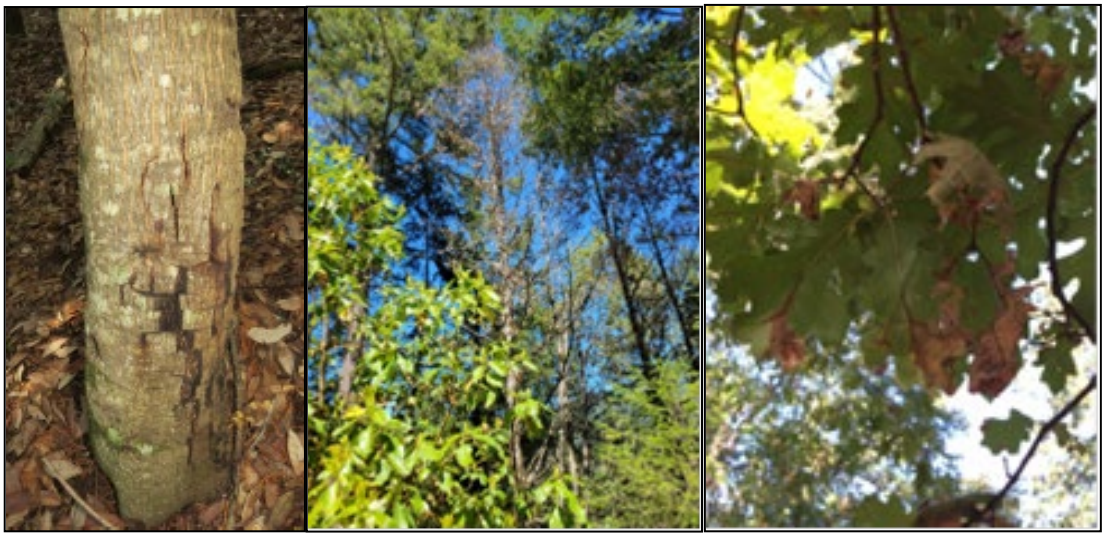
Rooney-Latham, S.; Blomquist, C.L.; Soriano, M.C. and Pastalka, T. 2022. First report of dieback caused by *Phytophthora ramorum* on golden chinquapin, *Chrysolepis chrysophylla*, in California. Plant Disease. https://doi.org/10.1094/PDIS-09-21-2044-PDN. (Early view.)

Golden or giant chinquapin, *Chrysolepis chrysophylla* (Fagaceae), is a slow growing, evergreen shrub or tree, native to the west coast of the US. In April 2015, several declining chinquapin trees were identified on Bolinas Ridge near Mt. Tamalpais in Marin Co. CA, a *Phytophthora ramorum* infested region. Affected trees were large overstory trees with dry, olivaceous colored foliage and thin canopies. Branch dieback was observed but no bole or branch cankers were observed. When the outer bark and epidermis were removed from the branches and water sprouts, dark brown vascular streaking was observed. Discolored xylem tissue (5-mm^2) was cultured on corn meal agar selective medium, CMA-PARP (Jeffers and Martin 1986). An organism morphologically resembling *P. ramorum* was isolated from one water sprout piece. DNA from the symptomatic plant tissue and a pure culture were extracted and amplified using oomycete specific PCR primers. To our knowledge, this is the first official detection of *P. ramorum* causing disease on *C. chrysophylla* in wildlands. Unlike other Fagaceae hosts of *P. ramorum*, external bole cankers were not seen on infected chinquapin trees. Branch isolation onto PARP media was difficult and detection by PCR from symptomatic vascular tissue was more efficacious. Losses of chinquapin in US forests due to *P. ramorum* would reduce forest diversity and could cause the loss of habitat for many animal species.

RELATED RESEARCH

Pérez-Sierra, A.; Chitty, R.; Eacock, A.; Jones, B.; Biddle, M.; Crampton, M.; Lewis, A.; Olivieri, L. and Webber, J.F. 2022. First report of *Phytophthora pluvialis* in Europe causing resinous cankers on western hemlock. New Disease Reports. 45(1): e12064.

2021 California Coast survey



Left. Figure 1. Bleeding canker caused by *Diplodia corticola* symptoms on tanoak. Photo courtesy Phytosphere Research. Middle. Figure 2. Tanoak mortality associated with *Tubakia californica* infection. Photo: CAL FIRE. Right. Leaf lesions caused by *Tubakia californica* on California black oak; note association with leaf veins. Photo: CDFA.

A high prevalence of tanoak and oak dieback and mortality was observed throughout north coastal California in 2021. To determine the causal agents and see if any of the mortality was due to *P. ramorum*, a survey of symptomatic trees was conducted by UC Cooperative Extension Humboldt-Del Norte and CAL FIRE Forest Entomology and Pathology. Sampled symptomatic tissues included twigs, leaves, and parts of cankered branches or boles. *Tubakia californica* was the fungus most commonly recovered. Most of the isolated fungi were endophytic, also known as "latent pathogens".

Oak and tanoak mortality caused by the pests recovered in this survey often strongly resembled mortality caused by *P. ramorum*. This overlap in appearance caused some confusion about the distribution and spread of the SOD pathogen on the landscape, especially in roadside and aerial surveys. However, weather conditions in 2021 were generally not conducive to *P. ramorum*, which spreads more rapidly and widely during extended warm, wet periods. A complete report and more pictures of symptoms and associated fungi are available HERE. For more information contact Chris Lee, christopher.lee@fire.ca.gov.

Meetings

The 10th Meeting of the International Union of Forest Research Organizations (IUFRO) Working Party S07.02.09 ***Phytophthora* in Forests and Natural Ecosystems** will be held June 19 – 25, 2022 at UC Berkeley. Field trips will feature sudden oak death along the coast and *Phytophthora* damage to manzanita in the Sierra Nevada foothills. The meeting is being organized by Matteo Garbelotto, UC Berkeley, Forest Pathology and Mycology Laboratory. For more information contact Doug Schmidt, dschmidt@berkeley.edu.