California Oak Mortality Task Force Report
AUGUST 2020

Monitoring

What's wrong with that tree? *Phytophthora* species infesting forests, urban plantings and restoration areas can cause symptoms on common *P. ramorum* host trees that are easy to confuse with those caused by *P. ramorum* itself. Especially confusing are symptoms and damage caused by *Phytophthora* species on tanoak (*Notholithocarpus densiflorus*), California bay laurel (*Umbellularia californica*) and madrone (*Arbutus menziesii*). Chris Lee, CALFIRE assembled photos and descriptions of symptoms caused by *P. cactorum, P. cinnamomi, P. cambivora* and other species (**more**).

Left: Dieback of tanoak associated with *P. cinnamomi*. Photo: C. Lee, Cal Fire.
Right: *Phytophthora pseudocryptogea* on coast live oak (*Quercus agrifolia*). Photo: K. Corrella, Cal Fire.

Regulations

In May 2020, APHIS posted a revised "APHIS List of Regulated Proven Hosts and Plants Associated with *Phytophthora ramorum*". This list is consistent with 7 CFR §301.92-2 (Restricted, regulated, and associated articles; lists of proven hosts and associated plant taxa).

Key updates include:

- *Gaultheria procumbens* (eastern teaberry) was moved to the proven hosts section based on completion of Koch's postulates (Osterbauer et al. 2014).

- Twenty-one species of plants were not included in the latest list compared to the 2013 Associated Plant list and are being further reviewed by APHIS: *Berberis diversifolia =Mahonia aquifolium, Cercis chinensis, Choisya ternata, Cornus kousa, Corylopsis spicata, Daphniphyllum glaucescens, Garrya elliptica, Ilex aquifolium, Lithocarpus glaber, Magnolia cavalieri, Magnolia denudata x salicifolia, Magnolia foveolata, Magnolia figo, Magnolia kobus, Magnolia liliiflora = Magnolia quinquepeta, Magnolia salicifolia = Magnolia proctoriana, Magnolia x thompsoniana (M. tripetala and M. virginiana), Physocarpus opulifolius, Ribes laurifolium,Vaccinium myrtilus and Vaccinium vitis-idaea*.
- Several plant taxa on the Associated Plant list have new scientific names, but to keep the list consistent with 7 CFR §301.92-2, they are listed by their older names, with the new names in parenthesis until changes are made in the Code of Federal Regulations (CFR).

APHIS is continuing to work on the regulated host list by reviewing scientific publications and research. For plant taxa that may need to be added to the regulated plant taxa list based on completion of Koch postulates, please contact Bill Wesela, USDA APHIS PPQ, National Policy Manager for *P. ramorum*, william.d.wesela@usda.gov.

References

Osterbauer, N.K.; Lane, S.; Trippe, A. 2014. *Phytophthora ramorum* identified infecting eastern teaberry (*Gaultheria procumbens*) plants shipped to Oregon. Plant Health Progress. 15(1): 9-10. doi/pdf/10.1094/PHP-BR-13-0109.

MONITORING

Utilizing "Structure from Motion" geospatial technology for the mapping of sudden oak death in Oregon. Since initial attempts to eradicate *P. ramorum* in Oregon proved only partially successful, land managers transitioned to a containment strategy that focuses on limiting its spread. A critical part of this containment strategy is being able to quickly identify new outbreaks. Since 2012, the Oregon Department of Forestry has acquired annual high resolution (30 cm), 4-band multispectral airborne imagery to quantify and monitor disease spread and intensification. Current methods that rely on photointerpretation and manual delineation to assess sudden oak death are inefficient and non-exhaustive.

Eric Rounds, Remote Sensing Specialist for the US Forest Service, partnered with Sarah Navarro, former Oregon Department of Forestry Forest Pathologist, to investigate whether "Structure from Motion" (SfM) workflows could be used to characterize the structure of infected and dead tanoak trees and detect changes in canopy morphology over time. Supervised image classification methods were also tested to see if tanoak trees potentially infected with *P. ramorum* could be detected over large areas in a semi-automated process. Findings showed that the high-resolution imagery available in the southwestern Oregon study area were not collected with the overlap necessary for SfM workflows, and the resulting data products were not sufficient for characterizing tanoak canopies. Moreover, while supervised classification methods were relatively successful at identifying dead tanoak, classification errors were prominent, particularly with dead conifer and bare-ground classes that were commonly confused with dead tanoak trees in classification outputs. The resulting classified products, however, could be used in conjunction with image mosaics to guide image interpretation efforts aimed at identifying dead and dying tanoaks prior to field validation. An example of the image interpretation may be viewed **here**. For more information contact Eric Rounds, eric.rounds@usda.gov.

NURSERIES

Washington State Department of Agriculture (WSDA) *P. ramorum* program update.
In June, WSDA conducted a trace-forward investigation on plants from a positive out-of-state nursery. Most plants had been sold at the retail level and were untraceable. However, 37 Rhododendron 'Polarnacht' had been installed in several residential locations in King County. Inspections were performed and samples collected on symptomatic trace-forward plants. So far six positive 'Polarnacht' have been detected at four sites. The Confirmed Residential Protocol has been enacted at all four locations.

In July, a two-day survey was conducted at the Kitsap County Botanical Garden first found positive for *P. ramorum* in 2015. A total of 229 samples were collected near previous positive sites and around the perimeter areas of the garden. Lab results are pending. For more information contact Scott Brooks, SBrooks@agr.wa.gov.

RESEARCH – ABBREVIATED ABSTRACTS

Capron, A.; Stewart, D.; Hrywkiw, K.; Allen, K.; Feau, N.; Bilodeau, G.; Tanguay, P.; Cusson, M. and Hamelin, R.C. 2020. *In situ* processing and efficient environmental detection (iSPEED) of tree pests and pathogens using point-of-use real-time PCR. PloS one. 15(4): e0226863. https://doi.org/10.1371/journal.pone.0226863

Global trade and climate change are responsible for a surge in foreign invasive species and emerging pests and pathogens across the world. Early detection and surveillance activities are essential to monitor the environment and prevent or mitigate future ecosystem impacts. Molecular diagnostics by DNA testing has become an integral part of this process. However, for environmental applications, there is a need for cost-effective and efficient point-of-use DNA testing to obtain accurate results from remote sites in real-time. This requires the development of simple and fast sample processing and DNA extraction, room-temperature stable reagents and a portable instrument. We developed a point-of-use real-time Polymerase Chain Reaction system using a crude buffer-based DNA extraction protocol and lyophilized, pre-made, reactions for on-site applications. We demonstrate the use of this approach with pathogens and pests covering a broad spectrum of known undesirable forest enemies: the fungi *Sphaerulina musiva*, *Cronartium ribicola* and *Cronartium comandrae*, the oomycete *Phytophthora ramorum* and the insect *Lymantria dispar*. We obtained positive DNA identification from a variety of different tissues, including infected leaves, pathogen spores, or insect legs and antenna. The assays were accurate and yielded no false positive nor negative. Finally, successful tests conducted with portable thermocyclers and disposable instruments demonstrate the suitability of the method, named *in Situ* Processing and Efficient Environmental Detection (iSPEED), for field testing. This kit fits in a backpack and can be carried to remote locations for accurate and rapid detection of pests and pathogens.

Cobb, R.C.; Haas, S.E.; Kruskamp, N.; Dillon, W.W.; Swiecki, T.J.; Rizzo, D.M.; Frankel S.J. and Meentemeyer, R.K. 2020. The magnitude of regional-scale tree mortality caused by the invasive pathogen *Phytophthora ramorum*. Earth's Future. doi: 10.1029/2020EF001500. https://doi.org/10.1029/2020EF001500 .

Forest pathogens are important drivers of tree mortality across the globe but it is exceptionally challenging to gather and build unbiased quantitative models of their impacts. Here we harness the rare dataset matching the spatial scale of pathogen invasion, host, and disease heterogeneity to estimate infection and mortality for the four most susceptible host species of *Phytophthora ramorum*, an invasive pathogen that drives the most important biological cause of tree mortality in a broad geographic region of coastal California and southwest Oregon. As of 2012, the most current field survey year, we estimate 17.5 (± 4.6 95% CI) million tanoak (*Notholithocarpus densiflorus)* stems were pathogen-killed with an additional 71 (± 21.5) million infected. We estimated 9.0 million (± 2.2) coast live oak (*Quercus agrifolia)* and 1.7 million (± 0.5) California black oak (*Quercus kelloggii*) stems are disease impacted (mortality and infection combined). Lastly, our estimates suggest infection in 95.2 million (± 8.6) California bay laurel (*Umbellularia californica*), which does not suffer mortality from infection and represents a critical source of continued spread. Prevalent infection as of 2012 suggests the cumulative number of disease-killed stems likely increased from 20.8 to 42.8 million between 2012 and 2019 for all species. While these impacts are substantial, most host populations occur in a yet to be invaded region of northern California indicating that the disease will intensify in the coming decades.

Garbelotto, M.; Popenuck, T.; Hall, B.; Schweigkofler, W.; Dovana, F.; Goldstein De Salazar, R.; Schmidt, D. and Sims, L. *First Look*. Citizen science uncovers *Phytophthora ramorum* as a threat to several rare or endangered California manzanita species. Plant Disease. https://doi.org/10.1094/PDIS-03-20-0619-RE.

The Sudden Oak Death or SOD Blitzes consist of yearly surveys led by citizen scientists designed to map the distribution of *Phytophthora ramorum*, causing the forest disease called SOD, across Northern California. During the 2017 Santa Cruz County SOD Blitz, six rare or endangered *Arctostaphylos* (manzanita) species were found to be possibly symptomatic for the first time. Symptoms included branch cankers and associated canopy mortality, and affected multiple individuals per species. Isolates of *P. ramorum* were obtained from each of the six species and through a 30-day long inoculation experiment on live plants, Koch's postulates were completed for each one of them, conclusively determining that they all are hosts of this pathogen. Two additional manzanita species were later found to be apparently symptomatic in Marin County. Inoculations on detached branches using an isolate of *P. ramorum* obtained from one of the six rare species from Santa Cruz County were successful, suggesting these two species may also be hosts of *P. ramorum*. Detached leaves of all eight species were also successfully inoculated at U.C. Berkeley in the fall of 2018 and then again in the spring of 2019. In these cases, the same isolate was used for all inoculations, in order to obtain information on the comparative susceptibility of the eight species in question. Both branch and leaf inoculations identified significant interspecific differences in susceptibility. The production of sporangia was low on all species, but it was not zero, suggesting that sporulation may cause within-plant and limited across-plant contagion, especially in rainy years.

Gaydos, D.A. 2020. Engaging forest stakeholders in disease management through participatory modeling. PhD thesis. Forestry and Environmental Resources. North Carolina State University. Raleigh, North Carolina. 155 pg. https://repository.lib.ncsu.edu/bitstream/handle/1840.20/37546/etd.pdf?sequence=1.

Globally, invasive forest pests and pathogens kill millions of trees every year, triggering the long-term restructuring of forest ecosystems and how they function. These impacts can be far-reaching, not only ecologically, but socially and economically. Management to minimize spread into new territories can potentially prevent the worst environmental and economic consequences, but decision-makers struggle to contain large-scale invasions with limited resources. As outlined in Chapter 1, successful disease control may hinge on stakeholders' collective understanding of spread patterns and how different treatment strategies are likely to impact those patterns. Fortunately, researchers have developed geospatial forecasts which project landscape-scale spread and impacts and enable the experimental evaluation of intervention strategies. However, the technological expertise required to develop and apply such tools makes them inaccessible to most decision-makers. This knowledge-practice gap is common in environmental modeling and limits forecasts' potential to guide coordinated, strategic responses. Studies are beginning to demonstrate the value of participatory modeling, or designing and applying models in collaboration with stakeholders, to bridge this gap. By guiding development, stakeholders ensure that the forecast meets their needs, while simultaneously learning about forecast functionality and how to interpret projections. This dissertation investigates how participatory methods can fuel the collaborative development and application of forecasts for forest disease control.

Yuzon, J.D.; Travadon, R.; Malar C.M.; Tripathy, S.; Rank, N.; Mehl, H.K.; Rizzo, D.M.; Cobb, R.; Small, C; Tang, T.; McCown, H.E.; Garbelotto, M. and Kasuga, T. 2020. Asexual Evolution and Forest Conditions Drive Genetic Parallelism in *Phytophthora ramorum*. Microorganisms. 8(6): 940.

It is commonly assumed that asexual lineages are short-lived evolutionarily, yet many asexual organisms can generate genetic and phenotypic variation, providing an avenue for further evolution. Previous work on the asexual plant pathogen *Phytophthora ramorum* NA1 revealed considerable genetic variation in the form of Structural Variants (SVs). To better understand how SVs arise and their significance to the California NA1 population, we studied the evolutionary histories of SVs and the forest conditions associated with their emergence. Ancestral state reconstruction suggests that SVs arose by somatic mutations among multiple independent lineages, rather than by recombination. We asked if this unusual phenomenon of parallel evolution between isolated populations is transmitted to extant lineages and found that SVs persist longer in a population if their genetic background had a lower mutation load. Genetic parallelism was also found in geographically distant demes where forest conditions such as host density, solar radiation, and temperature, were similar. Parallel SVs overlap with genes involved in pathogenicity such as RXLRs and have the potential to change the course of an epidemic. By combining genomics and environmental data, we identified an unexpected pattern of repeated evolution in an asexual population and identified environmental factors potentially driving this phenomenon.

Related Research

Khdiar, M.Y.; Barber, P.A.; Hardy, G.E.; Shaw, C.; Steel, E.J.; McMains, C. and Burgess, T.I. 2020. Association of *Phytophthora* with declining vegetation in an urban forest environment. Microorganisms. 8(7): 973. https://www.mdpi.com/2076-2607/8/7/973.

Molnar, C.; Nikolaeva, E.; Kim, S.; Olson, T.; Bily, D.; Kim, J.E. and Kang, S. 2020. *Phytophthora* diversity in Pennsylvania nurseries and greenhouses inferred from clinical samples collected over four decades. Microorganisms. 8(7): 1056, https://doi.org/10.3390/microorganisms8071056.

Redekar, N.R.; Bourret, T.B.; Eberhart, J.L.; Johnson, G.E.; Pitton, B.J.L.; Haver, D.L.; Oki, L.R. and Parke, J.L. 2020. The population of oomycetes in a recycled irrigation water system at a horticultural nursery in southern California. Water Research. 183. **https://doi.org/10.1016/j.watres.2020.116050**.

Serrano, M.S. and Garbelotto, M. 2020. Differential response of four Californian native plants to worldwide *Phytophthora cinnamomi* genotypes: implications for the modeling of disease spread in California. European Journal of Plant Pathology. 156(3): 851-866.

Resources

Frankel, S.J.; Alexander, J.M., tech. cords. 2020. Proceedings of the seventh sudden oak death science and management symposium: healthy plants in a world with *Phytophthora*. Gen. Tech. Rep. PSW-GTR-268. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 121 p.

The Proceedings of the Seventh Sudden Oak Death Science Symposium, held June 25–27, 2019, in San Francisco, is now available on the US Forest Service Pacific Southwest Research Station website. The volume contains about 50 abstracts or papers on all aspects of sudden oak death and Phytophthoras in native habitats.

A recording of the Phytophthoras in Native Habitats Work Group meeting held June 30, 2020 is now available. Presentations include a recently recognized *Phytophthora* infestation on rare manzanita in Sonoma Co., *Phytophthora* tree damage along the California North Coast, testing strategies prior to nursery stock outplanting and more.

The UC Oaks website has been redesigned to feature oak ecology, management and conservation information based on over 30 years of research. The site is managed by the University of California Cooperative Extension, Oak Woodland Conservation Workgroup.

People

Devon Gaydos recently joined the USDA Animal Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ) in Raleigh, NC. She will conduct participatory modeling for pests and pathogens using the techniques developed during her PhD research on "Tangible Landscape" (https://tangible-landscape.github.io/) at North Carolina State University, under the direction of Ross Meentemeyer. Dr. Gaydos may be reached at devon.gaydos@usda.gov.

CALENDAR

November 18-19, 2020. The 69th Annual Meeting of the California Forest Pest Council - 2020**,** on line. More details will be available soon or contact Kim Corella, Kim.Corella@fire.ca.gov.