CALIFORNIA OAK MORTALITY TASK FORCE REPORT
APRIL 2021

This issue features "Xuntapan'ámvaan: Acorn Eater - The Karuk and Sudden Oak Death" by Vikki Preston, Karuk Tribe Department of Natural Resources and summaries of several innovative research papers such as Thompson's study to determine if *Phytophthora ramorum* could be detected by "smell" on infected rhododendron plants. There are many exceptional papers in the Research section, starting on page 4.

TRIBAL SUDDEN OAK DEATH CONCERNS


Figures 1 & 2. Kade Whitecrane baiting for *Phytophthora ramorum* and Julian Salinas participating in the 2019 SOD Blitz organized by the Karuk Tribe. Photos: Preston, Karuk Tribe

Xuntapan'ámvaan: Acorn Eater - The Karuk and Sudden Oak Death. Ayukii – Hello. My name is Vikki Preston and I'm a Karuk, Yurok, Paiute, and Pit River person. For the last 5 years I've participated in work associated with the Karuk Tribe's Department of Natural Resources and the issue of sudden oak death (SOD). Since the initial community event that drew my attention, I've joined a crew of local folks who have interest in learning about SOD and work to monitor its spread, build awareness, and study its potential effects on our community and landscape ecology. Only in the past two decades has SOD been in Humboldt County, or within the area neighboring the Karuk Aboriginal Territory where our work takes place. Our Tribal community has taken unique focus on this issue, and its impacts, or potential impacts, carry our work forward as we mobilize community and continued education on this disease (Fig. 1 &2).

The Karuk Tribe, like many local tribes, has a connection to the SOD issue, largely because of our cultural, ceremonial, ecological, and personal relationships with the land. *Phytophthora ramorum* has varying effects depending on the plant species, and in Karuk territory there are many host plant species. One of the species of concern in Karuk territory is *Notholithocarpus densiflorus,* or the tanoak tree, and in many SOD infected places of California and Oregon these

trees have seen incredibly high mortality rates due to the disease. Indigenous people of the Klamath area including the Karuk people have an intricate and long socio-ecological relationship with the land that includes the tanoak tree. Along with salmon, the tanoak acorns are one of the people's main sources of traditional food for this part of Northern California. We call them xunyav, or the "best acorns"; they are numerous and nutritious. Karuk landscape ecology has evolved with and depends on tanoak trees, many animals also eat and count on their acorns every year. Many species of plants and fungi also rely on the lifecycle of tanoak. Karuk people have always tended the tanoak groves with many traditional processes including the implementation of prescribed fire, and there are numerous principles of care for tanoak groves that are passed down through families and communities.

As Karuk people, we have always lived here, and we still live amongst the same tanoak groves that our families have always tended and gathered from. The process of eating tanoak acorns begins with tending, gathering, processing, and cooking. It takes many hands and a good amount of time to accomplish this, and we live in a way that there is a large social process around tanoaks. Families and villages can come together to gather, and from my own experience this work is extremely beneficial to a person's mental and physical health and well-being, both from the work and the healthy food provided after.

We have many stories about tanoak: it was given to the people by coyote at the same time as salmon, spread all over the Karuk world so the people could eat. We are who we are today because of these species; and because of our history with them in this place, tanoaks and acorns are a huge part of our identity as Karuk people.

All of these reasons are why tanoaks are important to us, but also why *P. ramorum* has the potential in Karuk territory to be disastrous. READ MORE.

MONITORING

SOD Blitz 2021 is seeking volunteers to survey their communities for *P. ramorum*. The schedule and training materials for SOD Blitz 2021 are now available. More than a dozen communities from San Luis Obispo north to Del Norte County are participating in this annual citizen-science *P. ramorum* survey. No previous experience is necessary; training is available online. Sampling protocols have been set up to be COVID-19 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

California Department of Food and Agriculture (CDFA) *P. ramorum* Program update. California's spring compliance inspections are underway. Nine California nurseries that were previously positive for *P. ramorum* are currently being inspected and sampled in compliance with federal regulations. At one previously positive nursery, 12 infected, 1-gallon *Loropetalum* sp. plants were detected in January. Four states and 41 counties were notified about

required trace-forward inspections. Inspections have been completed in all 41 counties and there were no additional positive plants found. Annual inspections at other nurseries and establishments with compliance agreements in quarantined counties are also being conducted. For more information contact Carolyn Lambert, CDFA at Carolyn.Lambert@cdfa.ca.gov.

Oregon Department of Agriculture *P. ramorum* Nursery Program update. The early part of 2021 was spent conducting delimitation work at an interstate shipper in Linn County that was confirmed positive in late November 2020. Since the nursery had not been selling material from this location since June 2020, no trace investigations were necessary. After two rounds of delimitation surveys, 26 plant, 1 water (taken from a puddle adjacent to a confirmed positive plant), and 18 soil samples were confirmed *P. ramorum* positive. After marking out destruction zones, the grower agreed to destroy all material within the quarantine and destruction zones around each confirmed positive plant. Approximately 2,000 plants were slated for destruction. The grower opted to close this growing location due to the large volume of material that was to be destroyed, the broad distribution across the property of both infected plants and infested soil, and a lack of resources to upgrade the facility. The nursery remains under a compliance agreement until all the material is destroyed and the site is fully fumigated. ODA officials are in contact with the owner to monitor progress and provide guidance.

Currently there are ten nurseries participating in the Oregon *P. ramorum* Nursery Program. Of these, eight are interstate shippers under federal compliance agreements (7 CFR 301.92). The nurseries are in Polk (1), Washington (1), Marion (3), Columbia (1), Lane (1), and Linn (1) Counties. The ODA also holds compliance agreements with two intrastate shippers, in Clackamas and Lincoln Counties, which are regulated under Oregon state quarantine and federal requirements (7 CFR 301.92 and OAR 603-052-1230).

Compliance surveys for the 2021 spring season began on March 1st. To date five nurseries have been inspected and sampled with results pending for three nurseries. Two nurseries had no detections, marking their sixth consecutive inspection with no *P. ramorum* found. They will be formally released for successfully completing program requirements. One released grower is an intrastate shipper located in Clackamas County, first confirmed in 2012; the other is an interstate shipper located in Marion County, also first confirmed in 2012. For more information please contact Chris Benemann, sbenemann@oda.state.or.us.

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 multiple receiving locations in Washington. Eight samples were collected at three locations and all samples tested negative. Spring certification surveys have been scheduled for the two regulated sites in Washington, an interstate shipping nursery and a botanical garden. For more information contact Scott Brooks, SBrooks@agr.wa.gov.

RESEARCH (EXCERPTS OR ABBREVIATED ABSTRACTS)

Elliott, M.; Rollins, L.; Bourret, T. and Chastagner, G. 2021. First report of leaf blight caused by *Phytophthora ramorum* on periwinkle (*Vinca minor*) in Washington State, USA. Plant Disease. https://doi.org/10.1094/PDIS-08-20-1721-PDN. (Early view.)

Phytophthora ramorum was recovered from symptomatic foliage of periwinkle at a botanical garden in Washington state in March 2015. Symptoms were tan colored lesions with a dark brown margin visible on both surfaces of the leaf and were found on wounds or around leaf margins. Periwinkle is native to Europe and is commonly used for ground cover in ornamental landscapes. It is known to be invasive in US forests near the urban/wildland interface. Potential spread of *P. ramorum* into Washington forests is of regulatory concern, as well as long distance spread to other states via nursery stock. *P. ramorum* was isolated from symptomatic foliage. Colony morphology and chlamydospore production were consistent with descriptions of *P. ramorum*, except that the isolate was slower growing and had irregular, non-wildtype morphology compared to other isolates of *P. ramorum*. Pathogenicity of *P. ramorum* to periwinkle was confirmed by completing Koch's Postulates.

Funahashi, F. and Parke, J.L. 2020. Soil solarization to eradicate soilborne *Phytophthora* spp. in container nurseries with surface gravel. J. Environ. Hort. 38(4): 158-167. http://dx.doi.org/10.24266/0738-2898-38.4.158

To describe the effect of soil solarization in the presence of a gravel layer on the soil surface of container nurseries, we investigated belowground temperatures and soil water potential during solarization with different thicknesses of a surface gravel layer (2.5 cm, 7.5 cm, or no gravel) (1 in, 3 in, or no gravel) in relation to survival of soilborne *Phytophthora* spp. inoculum. In field trials conducted for 4 weeks with *P. ramorum* and *P. pini* in San Rafael, California and with *P. pini* in Corvallis, Oregon, infested rhododendron leaf inoculum was placed on the surface, and at 5 cm (2 in) and 15 cm (6 in) below the surface. In solarized plots with thicker layers of gravel, inoculum buried in the soil layer was killed in shorter treatment periods by higher elevated temperatures. Inoculum at the surface and within the gravel layer was also killed, but showed greater tolerance to heat under the lower water potential conditions as compared to the soil layer. *P. pini* has a significantly longer survival in heat than *P. ramorum*, allowing it to serve as a conservative surrogate for *P. ramorum* in testing solarization outside the quarantine facility. This study demonstrates how presence of a gravel layer influences soil solarization effectiveness in reducing *Phytophthora* inoculum survival.

He, Y.; Chen, G.; Cobb, R.C.; Zhao, K. and Meentemeyer, R.K. 2021. Forest landscape patterns shaped by interactions between wildfire and sudden oak death disease. Forest Ecology and Management. 486: 118987. https://doi.org/10.1016/j.foreco.2021.118987

Forest ecosystems are increasingly affected by a range of tree mortality events, which may permanently alter forest functional traits and disrupt their ecosystem services. While individual forest disturbances are well studied, interactions between multiple disturbances and changes of spatial patterns of forested landscapes are rarely quantified. In this study, we aim to analyze the role of wildfire in the Big Sur ecoregion of California on the spread of *P. ramorum*, an invasive pathogen which causes sudden oak death, the most important driver of mortality across 1000 km of coastal, fire-prone mixed conifer, evergreen hardwood, and woodlands. We investigated two

questions specific to the impacts of these disturbances at the landscape scale: (i) did rates of *P. ramorum* caused tree mortality change after wildfire? (ii) Following the wildfire, to what degree did the continued disease-driven mortality alter forest distribution? To answer these questions, we analyzed remote-sensing-derived products of post-fire burn severity and maps of disease-driven tree mortality. Quantification of burn severity and post fire disease mortality for the burned and unburned areas provided reference conditions for statistical hypothesis tests. The results from statistical and three landscape pattern analyses (area, shape, and isolation) suggest a significant role of wildfire in the reemergence of this invasive pathogen. First, rates of disease caused mortality after wildfire was negatively associated with burn severity suggesting some fire-driven containment of disease during post-fire forest recovery. Second, disease was positively correlated with the distance to fire boundary in unburned areas suggesting the effects of fire on disease extended into unburned areas while attenuating with distance from the burn. Lastly, wildfire reduced area, edge density and isolation of healthy tree patches and these effects did not recover to pre-fire levels for any of the three metrics after eight years of vegetation recovery. Given the widespread prevalence of disease-driven mortality, the importance and frequency of fire, as well as the naturalization of *P. ramorum* across a broad geographic area, these fire-disease interactions have potential to shape forest structure and disease dynamics across millions of acres of forested wildlands in California and Oregon.

Jung, T.; Jung, M.H.; Webber, J.F.; Kageyama, K.; Hieno, A.; Masuya, H.; Uematsu, S.; Pérez-Sierra, A.; Harris, A.R.; Forster, J.; Rees, H.; Scanu, B.; Patra, S.; Kudláček, T.; Janoušek, J.; Corcobado, T.; Milenković, I.; Nagy, Z.; Csorba, I.; Bakonyi, J.; Brasier, C.M. 2021. The destructive tree pathogen *Phytophthora ramorum* originates from the laurosilva forests of East Asia. J. of Fungi 7: 226. https://doi.org/10.3390/ jof7030226.

Abstract: As global plant trade expands, tree disease epidemics caused by pathogen introductions are increasing. Since ca 2000, the introduced oomycete *P. ramorum* has caused devastating epidemics in Europe and North America, spreading as four ancient clonal lineages, each of a single mating type, suggesting different geographical origins. We surveyed laurosilva forests for *P. ramorum* around Fansipan mountain on the Vietnam-China border and on Shikoku and Kyushu islands, southwest Japan. The surveys yielded 71 *P. ramorum* isolates which we assigned to eight new lineages, IC1 to IC5 from Vietnam and NP1 to NP3 from Japan, based on differences in colony characteristics, gene x environment responses and multigene phylogeny. Molecular phylogenetic trees and networks revealed the eight Asian lineages were dispersed across the topology of the introduced European and North American lineages. The deepest node within *P. ramorum*, the divergence of lineages NP1 and NP2, was estimated at 0.5 to 1.6 Myr. The Asian lineages were each of a single mating type, and at some locations, lineages of "opposite" mating type were present, suggesting opportunities for inter-lineage recombination. Based on the high level of phenotypic and phylogenetic diversity in the sample populations, the coalescence results and the absence of overt host symptoms, we conclude that *P. ramorum* comprises many anciently divergent lineages native to the laurosilva forests between eastern Indochina and Japan.

Kasuga, T.; Hayden, K.J.; Eyre, C.A.; Croucher, P.J.P.; Schechter, S.; Wright, J.W. and Garbelotto, M. 2021. Innate resistance and phosphite treatment affect both the pathogen's and host's transcriptomes in the tanoak-*Phytophthora ramorum* pathosystem. J. of Fungi. 7(3): 198. https://doi.org/10.3390/jof7030198.

Phosphites have been used to control sudden oak death; however, their precise mode of action is not fully understood. To study the mechanism of action of phosphites, we conducted an inoculation experiment on two open-pollinated tanoak families, previously found to be partially resistant. Stems of treatment group individuals were sprayed with phosphite, and seven days later, distal leaves were inoculated with the sudden oak death pathogen *P. ramorum*. Leaves from treated and untreated control plants were harvested before and seven days after inoculation, and transcriptomes of both host and pathogen were analyzed. We found that tanoak families differed in the presence of innate resistance (resistance displayed by untreated tanoak) and in the response to phosphite treatment. A set of expressed genes associated with innate resistance was found to overlap with an expressed gene set for phosphite-induced resistance. This observation may indicate that phosphite treatment increases the resistance of susceptible host plants. In addition, genes of the pathogen involved in detoxification were upregulated in phosphite-treated plants compared to phosphite-untreated plants. In summary, our RNA-Seq analysis supports a two-fold mode of action of phosphites, including a direct toxic effect on *P. ramorum* and an indirect enhancement of resistance in the tanoak host.

Smart, A.; Byrne, J.; Hammerschmidt, R.; Snover-Clift, K.L.; Stack, J.P.; Brenes-Arguedas, T.; Jones, J.B. and Harmon, C.L. 2021. Evolving plant diagnostics during a pandemic. Plant Health Progress. https://doi.org/10.1094/PHP-08-20-0074-MR (Early view.)

The National Plant Diagnostic Network (NPDN), comprising diagnostic professionals from more than 70 pathology, entomology, and nematology laboratories, safeguards U.S. plant systems through accurate diagnosis and effective communications with clients, partners, and stakeholders. During a *P. ramorum* surge, regulatory plant inspectors collect representative samples from blocks of plants at nurseries and retail outlets, which can then be funneled to their state's NPDN laboratory for genus-level triage using a serological test. All the plants in a block are held from sale pending results of triage testing. Samples positive for *Phytophthora* sp. are then funneled to regional laboratories for *P. ramorum* qPCR testing. If samples from new locations or hosts test positive for *P. ramorum* in these laboratories, they are forwarded to the APHIS confirmatory laboratory, where regulatory confirmation includes further molecular diagnostics and can result in regulatory action to protect the nursery industry and natural ecosystems.

This system was successfully deployed throughout 2019 and 2020, when *P. ramorum* was detected in multiple states. State agricultural inspectors collected thousands of delimitation survey samples at wholesale and retail locations identified by tracing. More than a dozen NPDN laboratories triaged samples at the state level with genus-level enzyme-linked immunosorbent assay testing, quickly clearing thousands of negative plant samples and facilitating the release of nursery and retail stock for sale. Just 10% of those samples required qPCR at three certified NPDN regional center laboratories and the Pennsylvania Department of Agriculture laboratory. The funnel-and-filter system meant only 3% of the total samples were forwarded to the two APHIS laboratories for regulatory confirmation, well within their capacity at just 10% of the

surge that overwhelmed the laboratory in 2004. The retail impact of this funnel-and-filter system from January 1, 2019, to November 1, 2020, is estimated conservatively at 11,350 plant samples collected by inspectors and funneled to NPDN laboratories, where each sample represents a block of at least three plants in a nursery or retail setting, with a retail value of $30/plant, for a total retail value of $1,021,500. The estimated retail value of the plants cleared for commerce is $990,855 (97%).

Srivastava, V.; Roe, A.D.; Keena, M.A.; Hamelin, R.C. and Griess, V.C. 2021. Oh the places they'll go: improving species distribution modelling for invasive forest pests in an uncertain world. Biological Invasions. 23: 297–349. https://doi.org/10.1007/s10530-020-02372-9.

Invasive species pose significant threats to the economic and ecological stability of our forests. Given the potential impact of invasive species, tools are needed that will help prevent invasions, or enable effective early responses through robust interception and surveillance frameworks. Unfortunately, these programs are costly and require regional prioritization. Species distribution models (SDMs) are one approach used to identify areas at risk of invasion. SDMs are a combination of tools that translate environmental conditions from a species' known distribution to predict its potential distribution in a new habitat. These can be combined with climatic models that forecast future climate scenarios, providing further information on the future potential for invasion and spread. The information provided by SDMs is critical for conservation and management planning and for understanding invasive species ecology and behavior under changing climatic conditions.

Here we focused on four forest invasive species (FIS) to evaluate the effects of various SDM design strategies on FIS distribution predictions in Canada, as well as their overall global distributions. We feature four case studies: two insects (Asian longhorned beetle, *Anoplophora glabripennis*; Asian gypsy moth, *Lymantria dispar asiatica* and *L. d. japonica* and two pathogens (sudden oak death, *P. ramorum*; Dutch elm disease, *Ophiostoma ulmi* and *O. novo-ulmi*).

Thompson, C.H.; McCartney, M.M.; Roubtsova, T.V.; Kasuga, T.; Ebeler, S.E.; Davis, C. and Bostock, R.M. 2021. Analysis of volatile profiles for tracking asymptomatic infections of *Phytophthora ramorum* and other pathogens in *Rhododendron*. Phytopathology. (*First Look*). https://doi.org/10.1094/PHYTO-10-20-0472-R.

Phytophthora ramorum is an invasive, broad host-range pathogen that causes ramorum blight and sudden oak death in forest landscapes of western North America. In commercial nurseries, asymptomatic infections of nursery stock by *P. ramorum* and other *Phytophthora* species create unacceptable risk, and complicate inspection and certification programs designed to prevent introduction and spread of these pathogens. In this study, we continue development of a volatile organic compound (VOC)-based test for detecting asymptomatic infections of *P. ramorum* in *Rhododendron sp*. We confirm detection of *P. ramorum* from volatiles collected from asymptomatic root-inoculated *Rhododendron* plants in a nursery setting, finding that the VOC profile of infected plants is detectably different from that of healthy plants, both when measured from ambient VOC emissions and from VOCs extracted from leaf material. Predicting infection status was successful from ambient volatiles, which had a mean area under the curve (AUC) value of 0.71 ± 0.17, derived from corresponding receiver operating characteristic curves from an extreme gradient boosting discriminant analysis (XGB-DA). This compares with

extracted leaf volatiles, which resulted in a lower AUC value of 0.51 ± 0.21. In a growth chamber, we contrasted volatile profiles of asymptomatic *Rhododendron* plants having roots infected with one of three pathogens: *P. ramorum*, *P. cactorum* and *Rhizoctonia solani*. Each pathogen induced unique and measurable changes, but generally the infections reduced volatile emissions until 17 weeks after inoculation, when emissions trended upwards relative to mock-inoculated controls. Forty-five compounds had significant differences compared to mock-inoculated controls in at least one host-pathogen combination.

RELATED RESEARCH

Landa, B.B.; Arias-Giraldo, L.F.; Henricot, B.; Montes-Borrego, M.; Shuttleworth, L.A. and Pérez-Sierra, A. 2021. Diversity of *Phytophthora* species detected in disturbed and undisturbed British soils using high-throughput sequencing targeting ITS rRNA and COI mtDNA Regions. Forests. 12(2): 229. https://www.mdpi.com/1999-4907/12/2/229.

Puertolas, A.; Bonants, P.J.; Boa, E. and Woodward, S. 2021. Application of real-time PCR for the detection and quantification of oomycetes in ornamental nursery stock. J. of Fungi. 7(2): 87. https://www.mdpi.com/2309-608X/7/2/87.

Sims, L.L. and Garbelotto, M. 2021. *Phytophthora* species repeatedly introduced in Northern California through restoration projects can spread into adjacent sites. Biological Invasions. https://doi.org/10.1007/s10530-021-02496-6.

Solla, A.; Moreno, G.; Malewski, T.; Jung, T.; Klisz, M.; Tkaczyk, M.; Siebyla, M.; Pérez, A.; Cubera, E.; Hrynyk, H. and Szulc, W. 2021. Phosphite spray for the control of oak decline induced by *Phytophthora* in Europe. Forest Ecology and Management. 485: 118938. https://doi.org/10.1016/j.foreco.2021.118938.

RESOURCES

The California Department of Food and Agriculture (CDFA) and the National Ornamental Research Site at Dominican University of California (NORS-DUC) have developed a voluntary program for ornamental and native plant nurseries which encourages and guides the implementation of Best Management Practices (BMPs) in plant production systems. As stated on the program website, "CDFA does not provide a guarantee of pathogen-free plants produced through this program, but the implementation of BMPs in nursery production is known to reduce pests and disease."

The Phytophthoras in Native Habitats Work Group is piloting "Accreditation to Improve Restoration" (AIR) a BMP-based accreditation program targeted at nurseries growing plants for restoration. AIR's objective is to exclude *Phytophthora* from restoration nurseries.

PERSONNEL

Welcome Emily Pfeufer, new USDA oomycete researcher. Emily Pfeufer joined the USDA Agricultural Research Service, Foreign Disease Weed Science Research Unit in Ft. Detrick, MD in January 2021. Most recently she was an Assistant Extension Professor at the University of Kentucky, after finishing her Ph.D. in Plant Pathology from Penn State. Emily plans to conduct

research on downy mildew pathogens, especially of brassicas, as well as Phytophthoras, particularly *P. ramorum*. She may be reached at Emily.Pfeufer@usda.gov.

KUDOS

Congratulations to the Phytophthoras in Native Habitats Work Group for being recognized with a 2020 IPM Achievement Award from the California Department of Pesticide Regulation. As part of the award ceremony a 2.5 minute video was assembled to summarize their work. Watch the award video for Phytophthoras in Native Habitats Work Group.