CALIFORNIA OAK MORTALITY TASK FORCE REPORT
MAY 2016

MEETINGS

Be sure to register for the "Sixth Sudden Oak Death (SOD) Science Symposium: Biosecurity, Plant Trade, and Native Habitats," to be held June 20-23, 2016 at Ft Mason in San Francisco. The complete agenda and list of posters are now available at the conference website. Symposium activities on June 20th include a Phytophthoras Identification Workshop at UC Berkeley as well as an evening welcome reception at the Presidio Log Cabin. June 21st will feature a Managing Phytophthoras on Open Space Lands field trip to the San Francisco Peninsula, followed by a California Oak Mortality Task Force Management Committee meeting. For more details, or to register, go to http://ucanr.edu/sites/sod6/.

MONITORING

Monthly surveys of the Kitsap County botanical garden, where *P. ramorum*-positive plants were detected throughout 2015, were negative for the pathogen in February and March. Perimeter and riparian area surveys were conducted in outlying areas of the garden in April. Results are pending.

It has been 1 year since the first detection of *P. ramorum* on a mature *Pieris* at the garden. Since then, work has included multiple surveys, the removal and destruction of infected plants, soil steaming of infested areas, the improvement and rerouting of drainage, and the implementation of best management practices by garden staff to help prevent pathogen spread.

Eight eastern states participated in the 2015 National *P. ramorum* Early Detection Survey of Forests (AL, FL, GA, MS, NC, PA, SC, and TX). Three of the 566 samples taken were *P. ramorum* positive - two from AL (first detection in 2009) and one from NC (first detection in 2010). All samples were collected from streams associated with previously positive nurseries. The 2016 survey is underway and includes all states from the 2015 survey as well as TN. For more information, contact Jaesoon Hwang at jaesoonhwang@fs.fed.us.

NURSERIES

Fifteen Oregon nurseries are participating in the 2016 annual *P. ramorum* re-certification process - 11 are a part of the federal (interstate) certification program and four are part of the state (intrastate) program. As of April 20th, three nurseries in the federal program have been recertified for interstate shipping. Four of the federal program nurseries have had positive *P. ramorum* detections, three of which have opted to destroy all plants within designated quarantine zones, and one that is holding plants in their quarantine zone for the required 90 days following removal of infested material. For the four remaining federal program nurseries, sample processing or inspection are not yet complete. One of the state program nurseries has been recertified for intrastate shipping, while the others are scheduled for inspection within the next 6 weeks.

FUNDING

The Midpeninsula Regional Open Space District Board of Directors approved $524,000 for SOD and nursery-related Phytophthoras research and management over the next 10 years. Areas of focus will include SOD-related preventative treatments, tanoak resistance, and oak forest restoration, as well as further development of clean nursery practices. In 2005, the Board of Directors allocated $350,000 for a 10-year-period to address *P. ramorum* on their preserves. Funding was used to preventatively treat specimen host trees, map potentially resistant trees, and to fund research. For more information, contact Cindy Roessler at croessler@openspace.org.

RESEARCH

Cunniffe, N.J.; Cobb, R.C.; Meentemeyer, R.K.; Rizzo, D.M.; Gilligan, C.A. *In Press*. Modelling When, Where and How to Manage a Forest Epidemic, Motivated by Sudden Oak Death in California. Proceedings of the National Academy of Sciences. Abstract online at https://www.repository.cam.ac.uk/handle/1810/254932.

Abstract: Sudden oak death, caused by *Phytophthora ramorum*, has killed millions of oak and tanoak in California since its first detection in 1995. Despite some localized small-scale management, there has been no large-scale attempt to slow the spread of the pathogen in California. Here we use a stochastic spatially-explicit model parameterized using data on spread of *P. ramorum* to investigate whether and how the epidemic can be controlled. We find that slowing the spread of *P. ramorum* is now not possible, and has been impossible for a number of years. However, despite extensive cryptic (i.e. pre-symptomatic) infection, and frequent long-range transmission, effective exclusion of the pathogen from large parts of the state could, in principle, have been possible were it to have been started by 2002. This is the approximate date by which sufficient knowledge of *P. ramorum* epidemiology had accumulated for large-scale management to be realistic. The necessary expenditure would have been very large, but could have been greatly reduced by optimizing the radius within which infected sites are treated, and careful selection of sites to treat. In particular we find that a dynamic strategy treating sites on the epidemic wave-front leads to optimal performance. We also find that "front-loading" the budget, treating very heavily at the start of the management program, would greatly improve control. Our work introduces a framework to quantify the likelihood of success and risks of failure of management that can be applied to invading pests and pathogens threatening forests worldwide.

Gandolfo, D.S.; Mortimer, H.; Woodhall, J.W.; and Boonham, N. 2016. Fourier Transform Infra-Red Spectroscopy Using an Attenuated Total Reflection Probe to Distinguish between Japanese Larch, Pine, and Citrus Plants in Healthy and Diseased States. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 163: 181–188.

Abstract: FTIR spectroscopy coupled with an Attenuated Total Reflection (ATR) sampling probe has been demonstrated as a technique for detecting disease in plants.

Spectral differences were detected in Japanese Larch (*Larix kaempferi*) infected with *Phytophthora ramorum* at 3403 cm^{-1} and 1730 cm^{-1}, from pine (*Pinus* spp.) infected with *Bursaphelenchus xylophilus* at 1070 cm^{-1}, 1425 cm-1, 1621 cm^{-1} and 3403 cm^{-1} and from citrus (*Citrus* spp.) infected with '*Candidatus liberibacter*' at 960 cm^{-1}, 1087 cm^{-1}, 1109 cm^{-1}, 1154 cm^{-1}, 1225 cm^{-1}, 1385 cm^{-1}, 1462 cm^{-1}, 1707 cm^{-1}, 2882 cm^{-1}, 2982 cm^{-1} and 3650 cm^{-1}. A spectral marker in healthy citrus has been identified as Pentanone but is absent from the diseased sample spectra. This agrees with recent work by Aksenov, 2014. Additionally, the spectral signature of Cutin was identified in the spectra of *Pinus* spp. and *Citrus* spp. and is consistent with work by Dubis, 1999 and Heredia-Guerrero, 2014.

Grünwald, N.J.; Larsen, M.M.; Kamvar, Z.N.; Reeser, P.W.; Kanaskie, A.; Laine, J.; and Wiese, R. 2016. First Report of the EU1 Clonal Lineage of *Phytophthora ramorum* on Tanoak in an Oregon Forest. Plant Disease. 100(5): 1024.

Abstract: Initially reported in California as the causal agent of sudden oak death (SOD), efforts to limit spread of *Phytophthora ramorum* in Oregon natural forests have concentrated on quarantine regulations and eradication of the pathogen from infested areas. *P. ramorum* has four clonal lineages: NA1; NA2; EU1; and EU2 (Grünwald et al. 2012; Van Poucke et al. 2012). Forest infestations in Oregon have been limited to the NA1 clonal lineage, whereas EU1, NA1, and NA2 clonal lineages have all been found in U.S. nurseries (Kamvar et al. 2015; Prospero et al. 2007). In February 2015, in response to an aerial survey, *P. ramorum* was isolated from a dying *Notholithocarpus densiflorus* tree in the South Fork Pistol River drainage of Curry Co., Oregon. The isolated strain was identified as *P. ramorum* based on presence of chlamydospores, characteristic hyphae, and sporangial morphology. Microsatellite genotyping at 14 loci (Vercauteren et al. 2011) and comparison with reference cultures revealed that these isolates belonged to the EU1 clonal lineage. Subsequently, five more isolates were obtained from the original tree stump and the EU1 lineage was confirmed. Microsatellite alleles of the forest EU1 isolates were nearly identical to EU1 isolates collected in 2012 from a nearby nursery during routine *P. ramorum* nursery monitoring, except for one allele at locus PrMS145a. Interestingly, several isolates differed at locus ILVOPrMS131a within both the 2015 forest and the 2012 nursery findings with identical allele frequencies in each population for this locus. These data provide inconclusive support for the introduction of EU1 into Curry Co. from the 2012 populations found in nurseries, given that no direct match was found probably owing to the paucity of EU1 samples from nurseries. These results provide further evidence that multiple distinct *P. ramorum* introduction events into the Curry Co. forest are a critical component of the epidemic (Kamvar et al. 2015). The impact of the EU1 clonal lineage of *P. ramorum* on Oregon natural forests is uncertain, but it may result in potential sexual reproduction given that EU1 is of A1 mating type while the prior population consisted of NA1 A2 mating type individuals. While sexual populations of *P. ramorum* have not been observed in nature or were aberrant in the laboratory, the presence of both A1 and A2 mating types makes the potential for sexual recombination more likely. The EU1 forest infestation is undergoing eradication treatments. Additional monitoring is necessary to determine if the EU1 clonal lineage occurs elsewhere in Curry Co. forests.

Harris, A.R. and Webber, J.F. *In press*. Sporulation Potential, Symptom Expression and Detection of *Phytophthora ramorum* on Larch Needles and Other Foliar Hosts. Plant Pathology. DOI: 10.1111/ppa.12538.

Abstract: *Phytophthora ramorum* has caused extensive dieback and mortality of commercially grown Japanese larch (*Larix kaempferi*) in many parts of the UK as infected foliage generates spores which then cause bark lesions and girdling cankers on trees. Following inoculation individual needles of Japanese, European (*L. decidua*) and hybrid (*L.* x *eurolepis*) larch infected with *P. ramorum* could produce thousands of sporangia. Mean numbers of sporangia ranged from 806 to 1,778 per cm^2 (hybrid larch and Japanese larch respectively), surpassing mean sporulation levels on foliar hosts previously associated with *P. ramorum* outbreaks in Britain, namely *Rhododendron ponticum, Castanea sativa* and *Vaccinium myrtillus*. Sporulation on larch even exceeded that of California bay laurel (*Umbellularia californica*) which drives the Sudden Oak Death epidemic in California. Inoculation of foliage selected at different times of year revealed that foliage age significantly affected sporulation levels, but this varied with host species. However, symptom development and sporulation were often not correlated. Symptoms on larch were frequently insignificant or even absent at certain times of year, with sometimes the only evidence of infection being the emergence of sporangia from needles but without any sign of discolouration or necrosis. Plating infected but asymptomatic needles onto *Phytophthora* selective medium also often failed to yield the pathogen. Asymptomatic infection of larch needles apparently occurs but is only detectable with microscopy. More generally, we suggest that diagnosis of *Phytophthora* infection in conifers is often underestimated due to isolation difficulties and delayed symptom expression.

Prigigallo, M.I.; Abdelfattah, A.; Cacciola, S.O.; Faedda, R.; Sanzani, S.M.; Cooke, D.E.L.; and Schena, L. 2016. Metabarcoding Analysis of *Phytophthora* Diversity Using Genus-Specific Primers and 454 Pyrosequencing. Phytopathology. 106(3): 305-313.

Abstract: A metabarcoding method based on genus-specific primers and 454 pyrosequencing was utilized to investigate the genetic diversity of *Phytophthora* spp. in soil and root samples of potted plants, from eight nurseries. Pyrosequencing enabled the detection of 25 *Phytophthora* phylotypes distributed in seven different clades and provided a much higher resolution than a corresponding cloning/Sanger sequencing approach. Eleven of these phylotypes, including *P. cactorum*, *P. citricola* s.str., *P. palmivora*, *P. palmivora*-like, *P. megasperma* or *P. gonapodyides*, *P. ramorum*, and five putative new *Phytophthora* species phylogenetically related to clades 1, 2, 4, 6, and 7 were detected only with the 454 pyrosequencing approach. We also found an additional 18 novel records of a phylotype in a particular nursery that were not detected with cloning/Sanger sequencing. Several aspects confirmed the reliability of the method: (i) many identical sequence types were identified independently in different nurseries, (ii) most sequence types identified with 454 pyrosequencing were identical to those from the cloning/Sanger sequencing approach and/or perfectly matched GenBank deposited

sequences, and (iii) the divergence noted between sequence types of putative new *Phytophthora* species and all other detected sequences was sufficient to rule out sequencing errors. The proposed method represents a powerful tool to study *Phytophthora* diversity providing that particular attention is paid to the analysis of 454 pyrosequencing raw read sequences and to the identification of sequence types.

Tooley, P.W.; Browning, M.; and Shishkoff, N. 2016. Pyracantha 'Mohave' Fruit Infection by *Phytophthora ramorum* and Transmission of the Pathogen from Infected Fruit to Roots of *Viburnum tinus*. Plant Disease. 100(3): 555-560.

Abstract: Colonization of the fleshy fruit of *Cornus florida*, *C. kousa*, *Laurus nobilis*, *Malus hupehensis*, and *Pyracantha* 'Mohave' was observed following inoculation with sporangia of *Phytophthora ramorum*. However, abundant production of chlamydospores was only observed in the fruit of *Pyracantha* 'Mohave'. *Pyracantha* 'Mohave' fruit that had been inoculated with a *P. ramorum* sporangia suspension were placed in pots containing rooted cuttings of *Viburnum tinus* in a misting tent or in water-filled trays in a climate-controlled greenhouse. Runoff was collected for 24 to 30 days, and roots were plated after the final collection. Mean percent recovery from infected roots was not significantly different ($P = 0.05$, Tukey's test) between bottom-watered treatments in trays and misted treatments, averaging 58% for bottom-watered and 54% for mist treatments. The number of CFU collected in runoff from bottom-watered plants was consistently lower than that obtained from plants held under mist, likely due to desiccation of the fruit. The results show that root infection of *V. tinus* can occur by *P. ramorum* via infected fruit of *Pyracantha* 'Mohave'. This phenomenon represents a pathway of infection for *P. ramorum* not previously reported, which may play a role in disease epidemiology.

RELATED RESEARCH

Lott, M.J. and Rose, K. 2016. Emerging Threats to Biosecurity in Australasia: The Need for an Integrated Management Strategy. Pacific Conservation Biology. http://dx.doi.org/10.1071/PC15040.

RESOURCES

CalPhytos.org provides information and resources on Phytophthoras in California native plant habitats, nurseries, and restoration sites. This information is being developed by the Working Group for Phytophthoras in Native Habitats and is now part of the suddenoakdeath.org site, adding to the body of knowledge available about Phytophthoras impacting California wildlands. For more information, contact Janice Alexander at jalexander@ucanr.edu.

Bellgard, S.E.; Pennycook, S.R.; Weir, B.S.; Ho, W.; and Waipara, N.W. 2016. *Phytophthora agathidicida*. http://forestphytophthoras.org/species/agathidicida.

CALENDAR

5/14 – Sonoma County SOD Blitz Training; Sonoma Community Center; 276 East Napa St., Sonoma; 9:30 a.m. – 11:30 a.m.; For more information, contact Lisa Bell at lkbell@ucanr.edu.

5/14 – Sonoma County SOD Blitz Training; Graton Community Club; 8996 Graton Road, Graton; 9:30 a.m. – 11:30 a.m.; For more information, contact Lisa Bell at lkbell@ucanr.edu.

5/14 – Sonoma County SOD Blitz Training; Spring Lake Regional Park Environmental Discovery Center; 393 Violetti Road, Santa Rosa; 9:30 a.m. – 11:30 a.m.; For more information, contact Lisa Bell at lkbell@ucanr.edu.

5/14 – Sonoma County SOD Blitz Training; Cloverdale History Center and Museum; 215 North Cloverdale Blvd., Cloverdale; 10:00 a.m. – 12:00 p.m.; For more information, contact Lisa Bell at lkbell@ucanr.edu.

5/14 – Portola Valley SOD Blitz Training; Portola Valley Town Center, 765 Portola Rd., Portola Valley; 10:00 a.m. – 12:00 p.m.; For more information, contact Debbie Mendelson at naturemend@sbcglobal.net.

5/14 – Los Altos Hills SOD Blitz Training; Los Altos Hills Town Hall, Council Chambers; 26379 Fremont Rd., Los Altos Hills; 1:00 p.m. – 3:00 p.m.; For more information, contact Sue Welch at sodblitz09@earthlink.net.

5/20 – San Luis Obispo SOD Blitz Training; UC Cooperative Extension classroom; 2156 Sierra Way, San Luis Obispo; 6:00 p.m. – 8:00 p.m.; For more information, contact: Lauren Brown at lbrown805@charter.net.

5/21 – Mendocino SOB Blitz Training; Albion School: 30400 Albion Ridge Road, Albion; 10:00 a.m. – 12:00 p.m.; For more information, contact Mario Abreu at abreu@mcn.org or Nancy Morin at nancy.morin@nau.edu.

5/27 – Santa Cruz SOD Blitz Training; UC Santa Cruz Botanic Garden, UC Santa Cruz Campus; 1156 High St., Santa Cruz; 6:30 p.m. – 8:30 p.m.; For more information, contact Brett Hall at brett@ucsc.edu.

6/4 – Napa County SOD Blitz Training; Napa County Resource Conservation District Conference Room; 1303 Jefferson Street, Suite 500B; 10:00 a.m. – 12:00 p.m.; For more information, contact Bill Pramuk at info@billpramuk.com.

6/20 – 23/16 Sixth Sudden Oak Death Science Symposium: Biosecurity, Plant Trade, and Native Habitats; Fort Mason, San Francisco; For more information or to register, go to http://ucanr.edu/sites/sod6/. For questions, contact Katie Harrell at kpalmieri@berkeley.edu or (510) 847-5482.