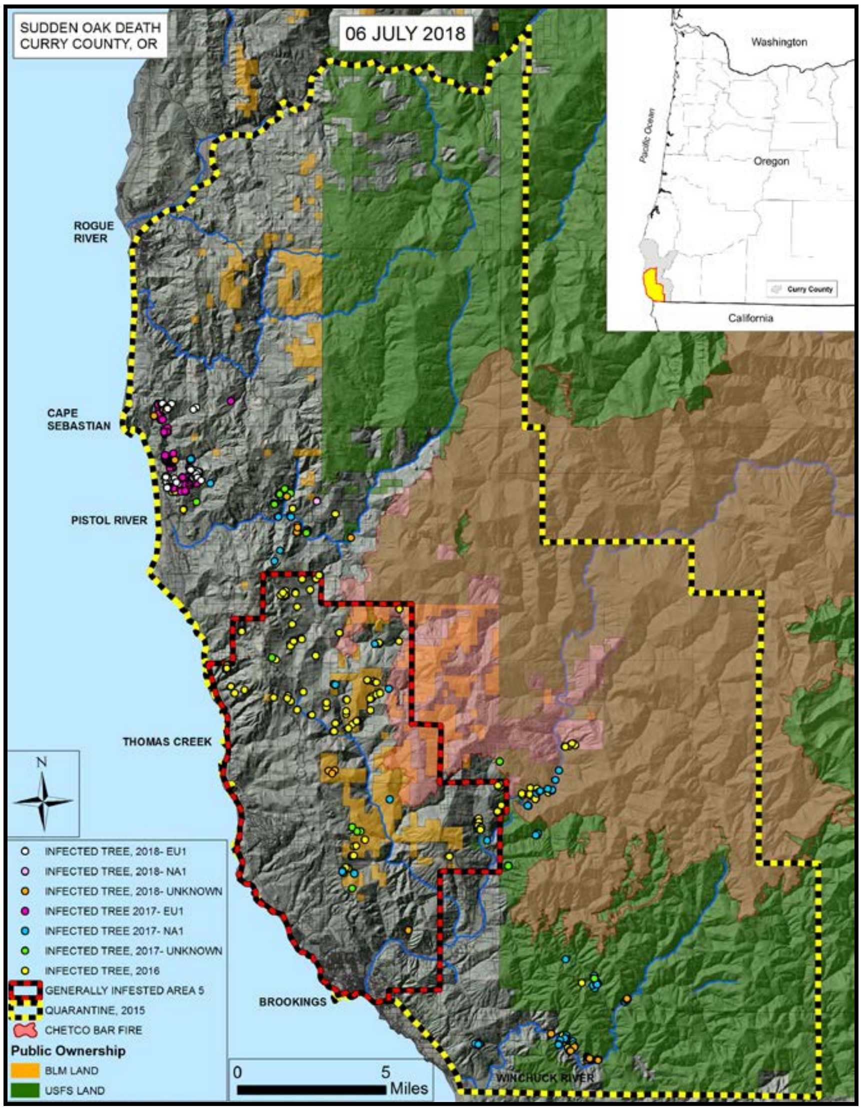
CALIFORNIA OAK MORTALITY TASK FORCE REPORT
JULY 2018

OREGON

***Phytophthora ramorum* detections in Oregon -** To date in 2018, 13 new infestations have been detected at or beyond the Generally Infested Area (GIA), including three new EU1 infestations and an intensification of two EU1 sites from 2017; all are well within the quarantine boundary (see map). Using a 300 ft treatment buffer, 2018 treatment areas to date total approximately 311 acres of private land and 10 USFS acres. The Oregon Department of Forestry has prioritized all EU1 infestations within the SOD quarantine area for treatment this year. Oregon's SOD stream baiting program commenced in early May with 46 stream drainages in and outside of the SOD quarantine area monitored this year.



Map showing P. ramorum *detections in Oregon. The recent EU1 detections are near Cape Sebastian and Pistol River. Map courtesy of ODF.*

REGULATIONS

The U.S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS) is proposing to revise the domestic regulations for *P. ramorum* (7 CFR 301). The revision codifies the changes made in Federal Orders in 2013-2016 and deregulates low-risk areas and nurseries. Based on nursery inspection data over a 9-year period, APHIS issued a series of Federal Orders to deregulate nurseries where the pathogen had never been found or had not been found recently. The Federal Orders also placed nurseries with recent detections under greater restriction and Federal oversight. The revision is open for comment until August 24, 2018. This notice may be viewed in the Federal Register at: http://www.regulations.gov/#!docketDetail;D=APHIS-2015-0101.

NURSERIES

***P. ramorum* has been found in 11 California nurseries in the first half of 2018.** A total of 6 California nurseries are now required to participate in bi-annual sampling to be compliant with Federal Order DA-2014-02, APHIS Revised *Phytophthora ramorum* Domestic Quarantine Regulatory Requirements for Certain Host Nurseries. The remainder of the positive nurseries are retail facilities detected with infested trace-forward plants. One nursery in a quarantined county is positive for the first time and the positive sample was confirmed by the USDA laboratory in Beltsville, MD.

The California Department of Food and Agriculture (CDFA) issued an advisory clarifying California's Nursery Stock Standards of Cleanliness related to *P. ramorum* positive articles in nurseries in all counties. Nursery Advisory No. 02-2018 states, plants that are infested with *P. ramorum* do not meet the California Nursery Stock Standards of Cleanliness (FAC 6902 and 3 CCR 3060.2) and may not be offered for sale. The current accepted protocol for delimitation, mitigation, and disposal of nursery stock, soil, and other articles that are infested with or may have been exposed to *P. ramorum* is the USDA *P. ramorum* Confirmed Nursery Protocol.

RESEARCH

Dale, Angela. 2018. Using genomic data to understand anthropogenic influences on oomycete and *Phytophthora* communities, and the evolution of an alien invasive species responsible for sudden oak death, *Phytophthora ramorum*. PhD Thesis. University of British Columbia. April 2018. 258 p. https://open.library.ubc.ca/cIRcle/collections/ubctheses/24/items/1.0365770

Emerging *Phytophthora* pathogens, often introduced, represent a threat to natural ecosystems. *Phytophthora* species are known for rapid adaptation and hybridization, which may be facilitated by anthropogenic activities. Little is known about natural *Phytophthora* and oomycete populations, or mechanisms behind rapid adaptation. We surveyed oomycete and *Phytophthora* communities from southwest B.C. under varying anthropogenic influences (urban, interface, natural) to determine effects on diversity, introductions and migration. We used DNA metabarcoding to address these questions on oomycetes. We then focused on *Phytophthora*, adding baiting and culturing methods, and further sub-dividing urban sites into agricultural or residential. Finally, we studied an alien invasive species, *Phytophthora ramorum* responsible for sudden oak death, and how it overcame the invasion paradox, limited to asexual reproduction and presumed reduced adaptability. Anthropogenic activities increase oomycete and *Phytophthora* diversity. Putative introduced species and hybrids were more frequent in urban sites. Migration is suggested by shared species between urban and interface sites, and two known invasive species found in natural and interface sites. Different anthropogenic activities influence different communities. Abundance increased for some species in either residential or agricultural sites. Two hybrids appear to be spreading in different agricultural sites. In the invasive *Phytophthora ramorum*, mitotic recombination drives diversification of the four lineages (NA1, NA2, EU1 and EU2), generating runs of homozygosity. One genome region, enriched in putative plant pathogenicity genes and transposons, was fixed in NA1 and present in eight EU1 individuals, but affecting the opposite alleles. Longer lesions during initial colonization in inoculated larch and Douglas-fir logs suggested a fitness advantage in these EU1 individuals. Mitotic recombination breakpoints were associated with transposons and low gene density. Noncore and lineage-specific genomic regions were enriched in putative plant pathogenicity genes and transposons. Gene loss was observed in the EU2 non-core genome affecting all effectors. A two-speed genome, where regions enriched in transposons and plant pathogenicity genes evolve faster, appears to drive non-core genome divergence, and mitotic recombination resulting in population evolution. This may explain invasion success and adaptability in *Phytophthora* pathogens. These results highlight the importance of anthropogenic activities in the emergence of forest diseases.

Elliott, M.; Yuzon, J.; Tripathy, S.; Bui, M.; Chastagner, G. A.; Coats, K.; Rizzo, D.M.; Garbelotto, M.; Kasuga, T. 2018. Characterization of phenotypic variation and genome aberrations observed among *Phytophthora ramorum* isolates from diverse hosts. BMC Genomics. 19(1): 320.

Background: Accumulating evidence suggests that genome plasticity allows filamentous plant pathogens to adapt to changing environments. Recently, the generalist plant pathogen *Phytophthora ramorum* has been documented to undergo irreversible phenotypic alterations accompanied by chromosomal aberrations when infecting trunks of mature oak trees (genus *Quercus*). In contrast, genomes and phenotypes of the pathogen derived from the foliage of California bay (*Umbellularia californica*) are usually stable. We define this phenomenon as host-induced phenotypic diversification (HIPD). *P. ramorum* also causes a severe foliar blight in some ornamental plants such as *Rhododendron* spp. and *Viburnum* spp., and isolates from these hosts occasionally show phenotypes resembling those from oak trunks that carry chromosomal aberrations. The aim of this study was to investigate variations in phenotypes and genomes of *P. ramorum* isolates from non-oak hosts and substrates to determine whether HIPD changes may be equivalent to those among isolates from oaks. **Results:** We analyzed genomes of diverse non-oak isolates including those taken from foliage of *Rhododendron* and other ornamental plants, as well as from natural host species, soil, and water. Isolates recovered from artificially inoculated oak logs were also examined. We identified diverse chromosomal aberrations including copy neutral loss of heterozygosity (cnLOH) and aneuploidy in isolates from non-oak hosts. Most identified aberrations in non-oak hosts were also common among oak isolates; however, trisomy, a frequent type of chromosomal aberration in oak isolates was not observed in isolates from *Rhododendron*. Conclusion: This work cross-examined phenotypic variation and chromosomal aberrations in *P. ramorum* isolates from oak and non-oak hosts and substrates. The results suggest that HIPD comparable to that occurring in oak hosts occurs in nonoak environments such as in *Rhododendron* leaves. *Rhododendron* leaves are more easily available than mature oak stems and thus can potentially serve as a model host for the investigation of HIPD, the newly described plant-pathogen interaction.

Schenck, N.; Saurat, C.; Guinet, C.; Fourrier-Jeandel, C.; Roche, L.; Bouvet, A.; Husson, C.; Saintonge, F-X.; Contal, C.; Ioos, R. 2018. First report of *Phytophthora ramorum* causing Japanese larch dieback in France. Plant Disease. First Look. https://doi.org/10.1094/PDIS-02-18-0288-PDN.

Phytophthora ramorum Werres, De Cock & Man in't Veld, an oomycete known in the USA as the causal agent of Sudden Oak Death, has spread across Europe since the early 2000s. It is responsible for damage and death to a wide range of plant species, including mature trees. In 2009 it was identified on Japanese larch (*Larix kaempferi*) in South-West England (Webber *et al*., 2010) and since, it has caused severe damages and losses to *Larix* spp. in the United Kingdom and the Republic of Ireland. There are two lineages of the oomycete EU1 and EU2 found in Europe (King *et al*., 2015), EU2 being the more aggressive. The symptoms on larch include necrosis and loss of needles, wilting of shoots, dieback of branches and death, often with abundant resin bleeding on trunks and branches. As sporulating hosts, *Larix spp.* may disperse *P. ramorum* over long distances. In May 2017, wilting, yellowing/reddening needles and branch mortality was observed on mature *Larix kaempferi* (about fifty years old) in the forest of Saint-Cadou, Finistère, in the far North western part of France (3° 59' 49.2'' W ; 48° 22' 22.4'' N). Approximately, 27% of the trees were affected in May, and 42% later in September 2017. The presence of *P. ramorum* was suspected, and was first confirmed by testing samples collected from trunks and branches with necrosis and resin bleeds, using the specific conventional PCR method developed by Ioos *et al*. (2006). The oomycete was also isolated in pure culture, using a *Phytophthora* selective medium (PARB[H]). The features observed, such as a coralloid mycelium, the presence of numerous, thin-walled chlamydospores (up to 75 µm large) and deciduous, semi-papillate sporangia arranged in clusters, matched those reported for *P. ramorum.* In June 2017, the presence of *P. ramorum* was confirmed in another larch stand in Hanvec, Finistère (4° 12' 45.0" W; 48° 20' 10.8" N), using the same identification techniques. In this stand, the prevalence was not precisely estimated, but was deemed much lower than in Saint-Cadou. Based on the analysis of *Cox1* partial sequence and the PCR-RFLP pattern described by Van Poucke *et al.* (2012) on *Cox1*, the *P. ramorum* isolates collected in these two forests could be assigned to the EU1 lineage. This is the first report of *P. ramorum* affecting Japanese larch in France and in mainland Europe. Until now it had only been detected on shrubs in nurseries, green spaces, and in rare circumstances in the natural environment on understory vegetation (rhododendron) in Normandy and Brittany, but not in the vicinity of the infected larch stands. The presence of this pathogen in the natural environment represents a major threat for larch trees, but also for the other potential forest host trees in this region, such as sweet chestnut and might have a severe impact on both forest and ornamental tree species. Research is in progress to learn more about this outbreak, the possible origin of the inoculum, the extension of the disease and its progression.

Seidl, R.; Klonner, G.; Rammer, W.; Essl, F.; Moreno, A.; Neumann, M.; Dullinger, S. 2018. Invasive alien pests threaten the carbon stored in Europe's forests. Nature Communications. 9(1): 1626.

Forests mitigate climate change by sequestering large amounts of carbon (C). However, forest C storage is not permanent, and large pulses of tree mortality can thwart climate mitigation efforts. Forest pests are increasingly redistributed around the globe. Yet, the potential future impact of invasive alien pests on the forest C cycle remains uncertain. Here we show that large parts of Europe could be invaded by five detrimental alien pests already under current climate. Climate change increases the potential range of alien pests particularly in Northern and Eastern Europe. We estimate the live C at risk from a potential future invasion as 1027 Tg C (10% of the European total), with a C recovery time of 34 years. We show that the impact of introduced pests could be as severe as the current natural disturbance regime in Europe, calling for increased efforts to halt the introduction and spread of invasive alien species. [*P. ramorum* is one of the five pests in this analysis.]

Shamoun, S.; Rioux, D.; Callan, B.; James, D.; Hamelin, R.; Bilodeau, G.; and others. 2018. An overview of Canadian research activities on diseases caused by *Phytophthora ramorum*: Results, progress and challenges. Plant Disease. 102(7): 1218-1233.

International trade and travel are the driving forces behind the spread of invasive plant pathogens around the world, and human mediated movement of plants and plant products is now generally accepted as the primary mode of their introduction, resulting in huge disturbance to ecosystems and severe socio-economic impact (Liebhold et al. 2012; Santini et al. 2013). These problems are exacerbated under the present conditions of rapid climatic change (Brasier 2008; Hansen 2008; Sturrock et al. 2011). We report an overview of the Canadian research activities on *Phytophthora ramorum* Werres, de Cock & Man in't Veld. Since the first discovery and subsequent eradication of *P. ramorum* on infected ornamentals in nurseries in Vancouver, British Columbia, in 2003, a research team of Canadian government scientists representing Canadian Forest Service (CFS), Canadian Food Inspection Agency (CFIA), and Agriculture and Agri-Food Canada (AAFC) worked together over a 10-year period and have significantly contributed to many aspects of research and risk assessment on this pathogen. The overall objectives of the Canadian research efforts were to gain a better understanding of the molecular diagnostics of *P. ramorum*, its biology, host-pathogen interactions, and management options. With this information it was possible to develop pest risk assessments (PRA) and evaluate the environmental and economic impact and future research needs and challenges relevant to *P. ramorum* and other emerging forest *Phytophthora* spp.

Tooley, P.W., and Browning, M. 2018. Sporangia production over time by *Phytophthora ramorum* on Rhododendron 'Cunningham's White' after placement at different relative humidities. Phytopathology. 108(6): 721-729.

We examined the impact of relative humidity (RH) on *Phytophthora ramorum* sporangia production on *Rhododendron* 'Cunningham's White'. When diseased plants were maintained under continuous moisture in a mist tent, sporangia were collected from some plants for 22 weeks. More than 3,000 sporangia/leaf/week were collected over the first 3 weeks but levels declined to <100 sporangia/leaf/week after 7 weeks. We also examined the impact of drying on

P. ramorum sporangia production. Diseased, detached leaves were maintained in humidity chambers (100, 96.2, 84.5, 74.9, and 56.2% RH) for up to 9 weeks and removed weekly to assess sporulation. For comparison, diseased leaves were harvested from plants maintained with dry foliage or subjected to 10 h of simulated dew nightly. All leaves supported sporulation following 5 weeks at 100% RH, 3 weeks at 96.2% RH, and 1 week at 84.5% RH. All leaves collected from plants subjected to nightly dew supported sporulation for 3 weeks; however, only 66.7% of leaves collected from plants with dry foliage supported sporulation after 1 week. Knowledge of the effects of RH levels on *P. ramorum* sporulation capacity will prove useful in terms of disease management recommendations and for development of predictive models and pest risk assessments.

RELATED RESEARCH

Jung, T.; Pérez-Sierra, A.; Durán, A.; Jung, M. H.; Balci, Y.; Scanu, B. 2018. Canker and decline diseases caused by soil-and airborne *Phytophthora* species in forests and woodlands. Persoonia. 40:182-220.

Simamora, A.; Paap, T.; Howard, K.; Stukely, M.J.C.; Hardy, G.E. StJ.; Burgess, T.I. 2018. *Phytophthora* contamination in a nursery and its potential dispersal into the natural environment. Plant Disease.102:132–9.

NORS-DUC

The National Ornamental Research Site (NORS-DUC) will host its 2018 Field Day on Wednesday, September 12 at their Dominican University of California facility in San Rafael. Topics include fungicides and biocontrol for Phytophthoras. The event is free but registration is required. To register and for more details, contact Karen Suslow, Karen.Suslow@dominican.edu by August 15th.

MEETINGS

Save the date: The Sudden Oak Death Seventh Science and Management Symposium (SOD7) is planned for June 25- 27, 2019 in the Greater Bay Area. The SOD7 will cover research and field activities for *Phytophthora ramorum* around the world as well as progress to address Phytophthoras in native habitats, restoration areas and native California plants. More details will be provided shortly.

CALENDAR OF EVENTS

11/13 - 14– 2018 California Forest Pest Council Annual Meeting at UC Davis. More information will be forthcoming soon.

06/25 - 27– 2019 Sudden Oak Death Seventh Science and Management Symposium. Location TBA. More information will be forthcoming soon.