Spread of *P. ramorum* from Nurseries into Waterways—Implications for Pathogen Establishment in New Areas[1]

Gary Chastagner,[2] Steven Oak,[3] Daniel Omdal,[4] Amy Ramsey-Kroll,[4] Katie Coats,[2] Yana Valachovic,[5] Chris Lee,[5] Jaesoon Hwang,[6] Steven Jeffers,[6] and Marianne Elliott[2]

Abstract

In the United States, water and soil baiting have been part of the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA APHIS) Confirmed Nursery Protocol (CNP) to prevent the spread of *Phytophthora ramorum* from infected nursery stock since 2005. Additionally, the U.S. Department of Agriculture, Forest Service (USDA FS) has, since 2006, supported the national early detection stream baiting survey of forests and urban areas to monitor the potential spread of this pathogen from nurseries and other high-risk settings. These surveys have been conducted in cooperation with universities and state forestry agencies. As a result of these activities, *P. ramorum* has been detected in waterways at 10 sites in six states between 2006 and June 2009 (fig. 1).

Below is a brief overview of these positive sites.

Florida - In 2006 and 2007, *P. ramorum* was recovered from standing and flowing water inside, but not outside, a retail garden center where *P. ramorum*-positive plants were present. In February 2008, *P. ramorum* was recovered from a drainage ditch at a nearby production nursery that was associated with the garden center site. Then, in December 2008 and again in March 2009, the pathogen was detected in bait leaves deployed in a stream outside this nursery.

Mississippi – *P. ramorum* was baited from a drainage ditch outside a nursery in December 2007. Subsequently, it was recovered from this ditch several times in 2008 and 2009 and a creek into which the ditch drains (using PCR on bait leaves) on multiple occasions from January 2008 through early 2009. Streamside vegetation surveys outside of the nursery resulted in PCR positives on two APHIS official host and associated host plant (HAP) (http://www.aphis.usda.gov/plant_health/plant_pest_info/pram/) samples in December 2007 and February 2008. To date, this is the only site where streamside vegetation surveys have detected *P. ramorum* on vegetation samples.

---

[1] A version of this paper was presented at the Fourth Sudden Oak Death Science Symposium, June 15-18, 2009, Santa Cruz, California.

[2] Washington State University, 2606 W. Pioneer, Puyallup, WA 98371-4998.
[3] USDA Forest Service, Southern Region, FHP, 200 WT Weaver Blvd, Asheville, NC 28804.
[4] Department of Natural Resources, P.O. Box 47037, Olympia, WA 98504-7037.
[5] University of California Cooperative Extension, Humboldt and Del Norte Counties, 5630 South Broadway, Eureka, CA 95503.
[6] Clemson University, Dept. of Entomology, Soils, & Plant Sciences, Clemson, SC 29634-0315.
Corresponding author: chastag@wsu.edu.

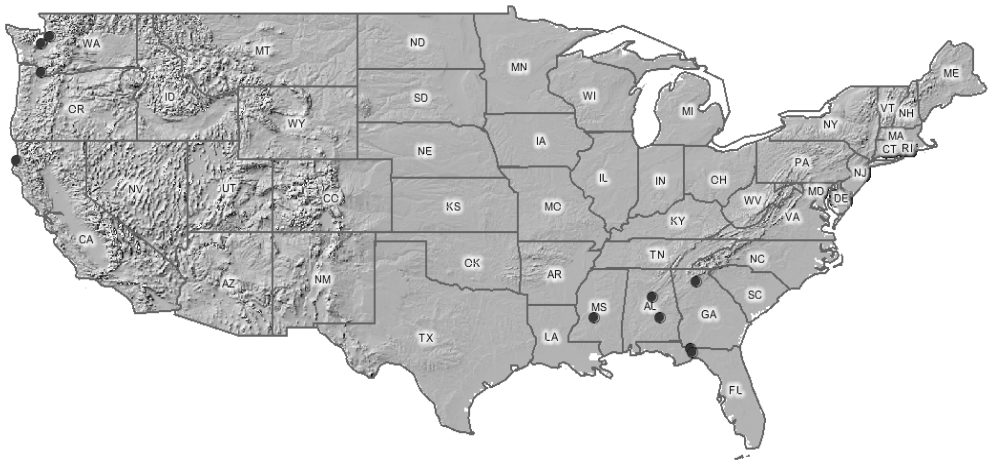

Figure 1—Locations where *Phytophthora ramorum* has been detected in waterways associated with nurseries.

Alabama – *P. ramorum* has been detected in drainage ditches along the edges of two nursery sites. At the first site, baits were negative in 2007, but were positive in November 2008 and March 2009. At the second site, baits were negative in 2007 and 2008, but were positive in March 2009.

Georgia – *P. ramorum* was baited from water draining off of a positive nursery site between December 2008 and March 2009. Bait positives were first obtained in February 2009 from a reservoir which is used for irrigation by the positive nursery, as well as an adjacent negative woody ornamental nursery and a homeowner's association in an adjacent subdivision. A stream draining the reservoir and nursery was bait-positive just off the nursery property in March, April, and May. Additional bait positives were obtained in April from one of two streams feeding the reservoir.

California – *P. ramorum* was baited from a small coastal stream in northern Humboldt County in 2006, with repeat detections in 2007 and 2009. A second stream tested positive in 2008 and 2009. Although there is a nearby nursery that tested positive for *P. ramorum* in 2004, 2006, and 2007 and a retention pond below the nursery that has tested positive in 2007, 2008, and 2009, no definitive linkage between the positive nursery and the retention pond has been made with the positive streams.

Washington – In western Washington, *P. ramorum* was first detected in a seasonal Pierce County stream associated with a positive nursery during early 2006. Baiting has detected the pathogen downstream from the original nursery site in 2007, 2008, and 2009. In King County in 2007, *P. ramorum* was detected in a retention pond outside of a positive nursery and a river into which the pond flows. The 2007 river positive bait site was positive again on two separate occasions in 2008. Extensive baiting of the river and retention pond during the first 6 months of 2009 has resulted in multiple positives at eight bait sites along the river and the retention pond. Genotyping data suggests that more than one source of inoculum may have contaminated this river. The river drains a watershed where a number of positive nurseries have been found and there are numerous, recently landscaped sites along the river. The most recent water detection in Washington occurred as the result of CNP activities at a positive nursery in Clark County in southwest Washington. Bait samples in a retention pond on this nursery and in a culvert on a drainage ditch running out of the pond at the lower property

edge, over 100 yards below the pond, tested positive in 2008. The retention pond tested positive again in 2009.

At the 2008 California Oak Mortality Task Force annual meeting, Steven Oak summarized a number of challenges relating to *P. ramorum* in rivers and streams. These included “the scale and connectivity of waterways, epidemiology unknowns, the ‘nature’ of riparian areas, treatment options, and regulatory gaps”.

The increased detection of *P. ramorum* in waterways associated with nurseries increases the risk that this pathogen will become established in urban landscapes. Likely pathways for *P. ramorum* to spread from contaminated waterways to vegetation include seasonal flooding and the use of water for irrigation. To date, *P. ramorum* has been detected on streamside vegetation at only one site. The spread of the pathogen from the stream to vegetation at this site appears to have resulted from direct exposure of susceptible host tissue to contaminated water during high stream flows. Diseases caused by *Phytophthora* spp., including *P. ramorum*, can also be spread by irrigating plants with contaminated sources of water. Currently, this appears to be a potentially significant issue at the Georgia and King County, Washington sites, where various entities have permits that allow them to use the contaminated water for irrigation purposes.

Efforts to reduce the risks associated with *P. ramorum* in waterways are hampered by a number of unanswered questions relating to the biology of this pathogen in this environment. For example, how is *P. ramorum* persisting and what is it sporulating on in the seasonal stream in Pierce County, Washington? Inoculum from a positive nursery spread into this stream during a flood event in early 2006. Although the nursery has tested negative every year since completion of the CNP in 2006 and the stream goes dry during the summer, *P. ramorum* has spread downstream from the initial positive bait site by the nursery and the stream has tested positive each year since 2006. Another question relates to inoculum thresholds required for infection of plant tissues during flooding episodes or when untreated contaminated water is used for irrigation.

Management of *P. ramorum* in waterways starts at the nursery. Educational programs are needed to increase the use of best management practices that are known to be effective in reducing development of *Phytophthora* diseases. This should include approaches, such as the use of biofilters, to reduce the risk that water leaving the nursery site contains viable inoculum. At this point it appears there are limited, if any, mitigation options for eliminating *P. ramorum* once it gets into a stream or river. It may be possible to eliminate inoculum in standing water in nurseries by treating it with algaecides or other chemicals, but these are not likely to be effective or environmentally acceptable in streams or rivers. The potential risk of spreading inoculum of this pathogen in irrigation water can be reduced by treatment of the water prior to irrigation.

Based on the growing number of sites where *P. ramorum* has been detected in waterways, increased monitoring of streams and rivers in areas where positive nurseries are located would provide a better understanding of the importance of this pathway in the overall spread of *P. ramorum* from nurseries to the urban environment. In areas such as the Puget Sound region of western Washington, where various state, community, and environmental groups are already monitoring streams and rivers, it may be possible to partner with these groups to expand these programs to include *P. ramorum*. Such a program might be patterned after Murdoch University’s "Fishing for *Phytophthora"* program to monitor and catalogue *Phytophthora* species in western Australia's rivers, streams, dams, and estuaries (http://www.fishingforphytophthora.murdoch.edu.au/). This would increase the level of monitoring activity beyond what is currently being done under the USDA FS national early detection stream baiting survey program and provide an excellent opportunity to increase public awareness about invasive pathogens such as *P. ramorum*. In conjunction with an increase in monitoring activities, an increased effort to genotype isolates and DNA samples

from nurseries and waterways would help clarify the origin of the inoculum that is spreading into waterways.

Finally, there are several regulatory issues that need to be addressed to reduce the risk that *P. ramorum* will spread from waterways to vegetation in the landscape. One issue is the current USDA APHIS concept of regulating "Diseases" caused by *P. ramorum*, but not the "pathogen." This results in questions relating to the roles and responsibilities of the various federal and state agencies in dealing with contaminated waterways. Another emerging issue relates to the notification of property owners who use water from contaminated waterways for irrigation. For example, Washington State Department of Ecology records (May 2009) indicate that 46 entities have water rights on the positive King County River. This includes a diverse group of landowners including farmers, a golf course, a turfgrass sod farm, municipalities, a church, and banks. A total of 35 permits specify the use of water for irrigation of various agricultural and horticultural crops, turf, and landscapes as well as newly established riparian plantings along the river. The total irrigated area listed by 31 of the entities is about 2,750 acres. Without some type of notification and educational program, property owners who pump water out of contaminated waterways may be inadvertently spreading *P. ramorum* over fairly large areas. This would counteract current efforts to contain the spread of *P. ramorum* and increase the risk of quarantine action by regulatory agencies.

Acknowledgments

The assistance of the Washington State Department of Agriculture and Gil Dermott at Washington State University, Puyallup are gratefully acknowledged.

Selected References

Hong, C.X.; Richardson, P.A.; Kong, P. and Bush, E.A. 2003. Efficacy of chlorine on multiple species of *Phytophthora* in recycled nursery irrigation water. Plant Disease. 87: 1183–1189.

Hwang, J.; Oak, S.W. and Jeffers, S.N. 2008. Detecting *Phytophthora ramorum* and other species of *Phytophthora* in streams in natural ecosystems using baiting and filtration methods. Proceedings of the Sudden Oak Death Third Science Symposium General Technical Report PSW-GTR-214. 55–58.

Hwang, J.; Oak, S.W. and Jeffers, S.N. 2009. Monitoring occurrence and distribution of *Phytophthora* species in forests streams in North Carolina using baiting and filtration methods. Proceedings of the Fourth Meeting of IUFRO Working Party S07.02.09: Phytophthoras in forests and natural ecosystems. General Technical Report PSW-GTR-211. 91–95.

Oak, S. 2008. Management challenges: *Phytophthora ramorum* in rivers and streams. COMTF Annual Meeting, San Rafael, CA. http://nature.berkeley.edu/comtf/pdf/2008Meeting/S.Oak_COMTF_2008.pdf.

Oak, S.; Elledge, A.; Yockey, E.; Smith, W. and Tkacz, B. 2008. *Phytophthora ramorum* early detection surveys for forests in the USA 2003-2006. Proceedings of the Sudden Oak Death Third Science Symposium General Technical Report PSW-GTR-214. 413–416.

Remigi, P.; Sutton, W.; Reeser, P. and Hansen, E. 2009. Characterizing the community of *Phytophthora* species in an Oregon forest stream. Proceedings of the Fourth Meeting of IUFRO Working Party S07.02.09: Phytophthoras in forests and natural ecosystems. General Technical Report PSW-GTR-211. 311–314.

Tjosvold, S.A.; Chambers, D.L.; Koike, S.T. and Mori, S.R. 2008. Disease on nursery stock as affected by environmental factors and seasonal inoculum levels of *Phytophthora ramorum* in stream water used for irrigation. Plant Disease. 92: 1566–1573.

Werres, S.; Wagner, S.; Brand, T.; Kaminski, K. and Seipp, D. 2007. Survival of *Phytophthora ramorum* in recirculating irrigation water and subsequent infection of *Rhododendron* and *Viburnum.* Plant Disease. 91: 1034–1044.