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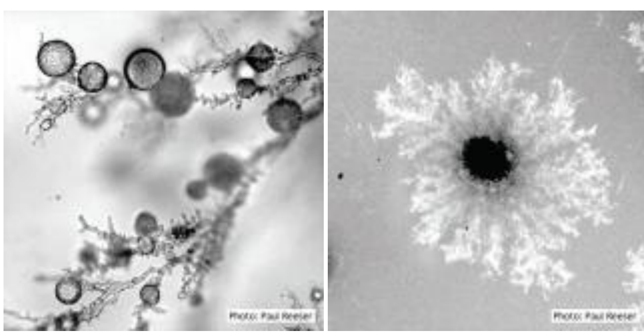
Phytophthora ramorum

Overview

P. ramorum Werres, De Cock, & Man in't Veld (2001) appears to be an exotic species introduced from an unknown origin to Europe and western N. America in the mid-1990s, likely on nursery plants (Mascheretti et al. 2008). In California and southwest Oregon, the pathogen spread to native oak and tanoak forests, where it causes lethal stem cankers ("sudden oak death"). More than a million trees have been killed (Meentemeyer et al. 2011). In Europe, where nurseries in over 20 countries reported *P. ramorum*, the disease on trees was limited to isolated stands of beech and oak associated with infected rhododendrons. In 2009, the pathogen began causing widespread mortality on Japanese larch timber plantations in the UK (Brasier & Webber 2010). International, national, state and county quarantines are in place to prevent the further spread of disease with nursery plants and to contain the infestation in forests. *P. ramorum* is unusual among forest *Phytophthora* species for its wide host range and infection of aerial plant parts.

Morphology

Sporangia (average 46–65 µm by 21–28 µm) formed on agar and in water, ellipsoid, spindle-shaped, or elongate-ovoid, semi-papillate, caducous with short pedicel (< 5 µm), produced singly or in clusters of 2–12 on sympodially branched sporangiophores. Chlamydospores (20–91 µm; average 46-60 µm) formed abundantly in agar, globose, mostly thin-walled, terminal or intercalary. Heterothallic, oogonia not seen in single culture (Werres et al. 2001).



Appearance of hyphae and chlamydospores on isolation plate (left). Distinctive appearance of growth from infected plant material on PAR isolation plate (right).

Cluster of ellipsoid–ovoid, semi-papillate sporangia (left). Caducous sporangium with short pedicel (right).

Genetics

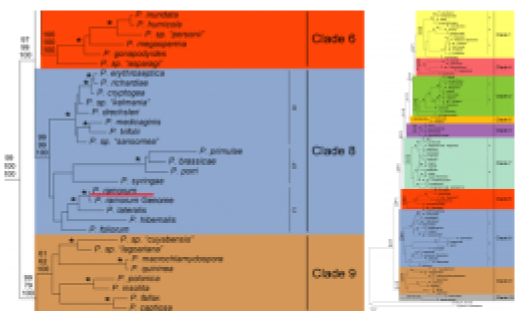
P. ramorum is placed in clade 8c, with *P. lateralis* as its closest relative (Blair et al., 2008). Populations in North America and Europe are clonal and belong to three lineages according to several molecular markers (Grünwald et al., 2008).

Table 1. Characteristics of clonal lineages of *P. ramorum* (adapted from Grünwald et al. 2009 and others)

Clonal lineage	**Distribution**	**Habitat**	**Mating type**
EU1	Europe, N. America	Nurseries, gardens, forest plantations	A1 (A2*)
NA1	N. America	Forests, nurseries	A2
NA2	USA	Nurseries	A2

*Most EU1 isolates are mating type A1 but several isolates from Belgium are mating type A2

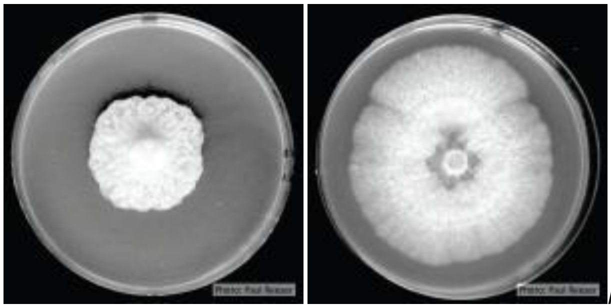
Evidence suggests that clonal lineages descended from a sexually recombining population but have been reproductively isolated for a long time (Goss et al. 2009). Oospores have not been observed under natural conditions despite the concurrent presence of both mating types in nurseries. A 7X draft whole-genome sequence (Tyler et al. 2006) and mitochondrial sequence (Martin et al., 2007) of *P. ramorum* are available.



Phylogenetic tree from http://www.phytophthoradb.org/ramorum (Blair et al 2008).

Growth

Temperature optimum ca. 20°C, min. ca. 2°C, max. ca. 26–30°C. Growth at 20°C on V8 agar 2.2 mm/d, on cornmeal agar-β sitosterol 1.9 mm/d, on cornmeal agar with pimaricin, ampicillin, and rifampicin (PAR) 0.7 mm/d, on potato dextrose agar 1.2 mm/d.


P, ramorum colony morphology at 14 days on potato dextrose agar (left) and V8 agar (right).

Distinguishing characteristics for identification

Colony morphology and hyphal characteristics on isolation plates are distinctive. The abundance of large chlamydospores in combination with clusters of semi-papillate, caducous, ellipsoid sporangia formed on the surface of the agar may be considered definitive. Be aware that these features may be seen independently in other *Phytophthora* species growing on isolation plates.

The searchable web-based database *Phytophthora*-ID is useful for rapid identification of *Phytophthora* species based on sequencing of the ITS or Cox spacer regions, followed by BLAST searching the database. *Phytophthora*-ID maintains a database of sequences that is selective for sequence accessions that come from trusted sources including published, peer-reviewed studies whenever possible.

Disease History

Increasing mortality of coast live oak and tanoak was noted in rural and suburban areas around the San Francisco Bay area beginning about 1995. Public awareness and research attention grew rapidly, and the syndrome was named "sudden oak death," but a causal agent was not proved until 2000, when a new *Phytophthora* species was isolated from stem cankers on dying trees (Rizzo et al. 2002). The California species proved to be identical to another unnamed *Phytophthora* detected in 1993 in Germany from declining rhododendron, and was ultimately named *P. ramorum*. Nurseries in California were first implicated as a disease source in 2001, and in 2003 it became evident that *P. ramorum* was in the nursery trade along the entire west coast of N. America, and was also widespread in European nurseries. Tree infections in Europe were limited to beech and non-native oak in southwest England and the Netherlands, often associated with infected rhododendrons. By 2009 the pathogen began to cause widespread damage to forest plantations of Japanese larch in the UK (Brasier & Webber 2010). International, national, and regional quarantines have been imposed to stop further spread of the pathogen. Efforts are focused on eradicating the pathogen from nurseries and containing the disease in forests. The pathogen is considered to have been introduced separately and relatively recently to both the US and Europe, although its native home is unknown (Mascheretti et al. 2008, Goss et al. 2009).

Impacts in the Forest

P. ramorum threatens the survival of tanoak in western parts of the tree's range and is reducing populations of coast live oak dramatically. More than a million trees in California and Oregon have been killed, and an epidemic is occurring on Japanese larch in the UK where more than 1500 ha of infested timber plantations have already been felled. Large areas of U.S. southeastern forests are considered at risk (summarized in Kliejunas, 2010) as are heathlands, oak and beech forests, evergreen oak woodlands and laurel forests in Europe (Sansford et al. 2009). *P. ramorum* spreads locally through rain splash of sporangia that form abundantly on the foliage of certain hosts, for example, California bay laurel, Japanese larch, *Rhododendron ponticum*, or on twigs of tanoak. Long distance aerial dispersal of sporangia is believed to occur infrequently during storms (Hansen et al. 2008). Although the pathogen does not appear to infect roots, soilborne chlamydospores can survive long periods (Fichtner et al. 2009) and give rise to new sporangia that are splashed or carried to infect above-ground parts of plants. *P. ramorum* has also been baited from forest streams in California and Oregon and from waterways near several infested nurseries.

Bark cracks with black ooze in coast live oak (*Quercus agrifolia*), a symptom of a *P. ramorum* canker (top). Tip symptoms on tanoak seedling (*Notholithocarpus densiflorus*), USA (bottom).

Forest and Wildland Hosts and Symptoms

Symptoms differ on different host species. The pathogen causes sudden oak death (SOD), characterized by lethal stem cankers, on some Fagaceae (oaks), shoot dieback on some Ericaceae and conifers, and foliar blight on a diverse group of hosts. *P. ramorum* has an extremely broad host range that includes more than 100 species in 37 families, although only a few forest species are highly susceptible. Many nursery hosts, such as rhododendron, camellia, and viburnum are important in long distance dispersal of the pathogen. *P. ramorum* is established in oak and tanoak forests in 14 coastal California counties, and in Curry County, Oregon, as well as in isolated forest estates in Europe. Timber plantations of Japanese larch in the UK are also infested.

The table of susceptible hosts below includes only the most ecologically and economically important host species. For a more complete list of the many other host species, download a pdf from APHIS (Animal and Plant Health Inspection Service of the U.S. Department of Agriculture) or FERA (Food and Environmental Research Agency of the U.K.). Our Disease Finder also includes more host species than this table.

Host Latin Name	Host Common Name	Symptoms	Habitat	Region
Fagus sylvatica	European beech	Canker	Forest, Parklands	Germany, Netherlands, United Kingdom
Larix kaempferi	Japanese larch	Canker, Dieback, Leaf necrosis	Plantations	Ireland, United Kingdom
Notholithocarpus densiflorus	Tanoak	Blight, Canker	Forest	USA - California, Oregon
Pseudotsuga menziesii	Douglas-fir	Dieback	Forest	USA - California
Quercus agrifolia	Coast live oak, Oak	Canker	Forest	USA - California

Host Latin Name	Host Common Name	Symptoms	Habitat	Region
Quercus chrysolepis	Canyon live oak, Oak	Canker	Forest	USA - California
Quercus falcata	Oak, Southern red oak	Canker	Forest, Parklands	United Kingdom
Quercus rubra	Northern red oak, Oak	Canker	Forest, Parklands	United Kingdom
Rhododendron hybrids	Rhododendron hybrids	Blight, Dieback	Ornamental Nursery	Canada - British Columbia, Europe, USA
Rhododendron macrophyllum	Pacific rhododendron	Blight, Dieback	Forest	USA - California, Oregon
Rhododendron ponticum	Pontic rhododendron	Blight, Dieback	Forest, Parklands	Ireland, United Kingdom
Sequoia sempervirens	Coast redwood	Dieback	Forest	USA - California
Umbellularia californica	California bay laurel, Myrtlewood	Blight	Forest	USA - California
Vaccinium ovatum	Evergreen huckleberry	Dieback	Forest	USA - California, Oregon

Management and Educational Materials

View additional educational and management resources on our Phytophthora Web Resources page. A comprehensive website on sudden oak death is available at www.suddenoakdeath.org.

Management of *P. ramorum*–associated diseases in forests, woodlands, and urban areas has taken a multiscale approach ranging from individual trees to landscapes to international quarantines (Alexander and Lee, 2010; Frankel, 2008; Rizzo et al., 2005). Disease prevention and mitigation at the individual plant level or urban–wildland interface in California has been focused on chemical control or other programs designed to maintain health of plants. Some fungicides have been developed that act as protectants (e.g., phosphonates) against infection, but few chemicals have been developed that work once the plant is infected (Garbelotto and Schmidt, 2009; Garbelotto et al., 2009). Removal of inoculum-producing plants, such as bay laurel or rhododendron, has also been important at smaller scales to protect high-value oaks (Swiecki and Bernhardt, 2008). Education and involvement of local communities has been critical at the urban–wildland interface to the implementation of management programs (Alexander and Lee, 2010).

At larger landscape scales in wildland forest communities, management strategies for *P. ramorum* have included prevention, eradication, treatment, and restoration (Rizzo et al., 2005). Eradication has been attempted in some cases, most notably with tanoak forests in Oregon (Kanaskie et al., 2010) and larch plantations in the United Kingdom (Brasier and Webber, 2010), but has met with mixed success. Important successes have been balanced by continuing tree mortality in many areas (Kanaskie et al., 2010). Difficulties have been encountered in detecting the pathogen at an early enough stage for eradication to be completely effective at a landscape scale. Cryptic infection (i.e., with minimal or no symptoms) of foliage during the initial invasion of a site by *P. ramorum* has allowed the pathogen to stay one step ahead of detection efforts in many cases. The development of management strategies, beyond eradication, for forest lands following invasion by *P. ramorum* is still in the early stages (Rizzo et al., 2005; Valachovic et al., 2008, 2010). Decision making requires the ability to fit disease management into the context of other management goals (e.g., fire prevention, wildlife) within the broader forest landscape (Rizzo et al., 2005). Examples of approaches that are being tested include forest stand thinning to remove inoculum-producing hosts and use of prescribed fire (Valachovic et al., 2008, 2010).

The broadest scale for disease management, regional to international, is driven by regulations and management practices designed to prevent further spread of *Phytophthora* (Brasier, 2008; Frankel, 2008; Rizzo et al., 2005). In recent years, broadening of national and international quarantines designed to prevent pathogen movement has led to an increased effort to manage all *Phytophthora* diseases in nursery settings (Osterbauer et al., 2004; Parke et al., 2010a,b). While dozens of plant species have been found infected in nurseries, the majority of infections have been associated with the genera *Rhododendron*, *Camellia*, *Pieris*, *Kalmiaem*, and *Viburnum* (Osterbauer et al., 2004; Parke et al., 2010a). These plant species have become the focal point for development of best management practices and pathogen detection strategies (Parke et al., 2010a). The need for pathogen detection in nursery plants as part of quarantine inspections has resulted in the development of a number of PCR-based molecular tests (e.g., Hayden et al., 2004; Vettraino et al., 2010).

- Consultation on future management of risks from *Phytophthora ramorum* and *Phytophthora kernoviae*
- *Phytophthora ramorum* - A threat to our woodlands, heathlands and historic gardens - Plant Disease Factsheet
- *Phytophthora ramorum* - A practical guide for the Nursery Stock and Garden Centre Industry
- *Phytophthora ramorum* A Practical Guide for Established Parks & Gardens, Amenity Landscape and Woodland Areas
- Nursery guide for diseases caused by Phytophthora ramorum on ornamentals: diagnosis and management
- Protecting trees from sudden oak death before infection
- Muerte subita de Robles (Sudden oak death)
- Nursery industry best management practices for *Phytophthora ramorum*
- Life Cycle of *Phytophthora ramorum* As it relates to soil and water
- Risk Analysis for *Phytophthora ramorum* Werres, de Cock & Man in't Veld, Causal Agent of Sudden Oak Death, Ramorum Leaf Blight, and Ramorum Dieback
- Sudden oak death and Phytophthora ramorum: a summary of the literature
- *Phytophthora ramorum* - Identifying symptomatic larch

References

Alexander, J, Lee C. 2010. Lessons learned from a decade of sudden oak death in California: evaluating local management. Environmental Management 46:315-328.

Blair, JE, Coffey MD, Park S-Y, Geiser DM, Kang S. 2008. A multi-locus phylogeny for *Phytophthora* utilizing markers derived from complete genome sequences. Fungal Genetics and Biology 45:266-277.

Brasier, CM, Rose J, Kirk SA, Webber JF. 2002. Pathogenicity of *Phytophthora ramorum* isolates from North America and Europe to bark of European Fagaceae, American *Quercus rubra* and other forest trees. Sudden Oak Death Science Symposium, 15-18 December 2002, Monterey, CA.

Brasier, C. 2003. Sudden oak death: *Phytophthora ramorum* exhibits transatlantic differences. Mycological Research 107:257-259.

Brasier, C, Denman S, Brown A, Webber J. 2004. Sudden oak death (*Phytophthora ramorum*) discovered on trees in Europe. Mycological Research 108:1108-1110.

Brasier, CM. 2008. The biosecurity threat to the UK and global environment from international trade in plants. Plant Pathology 57:792–808.

Brasier, C, Webber J. 2010. Plant pathology: sudden larch death. Nature. 466(7308):824-825.

Brown, AV, Brasier CM. 2007. Colonization of tree xylem by *Phytophthora ramorum*, *P. kernoviae* and other *Phytophthora* species. Plant Pathology 56:227–241.

Chadfield, V, Pautasso M. 2011. *Phytophthora ramorum* in England and Wales: which environmental variables predict county disease incidence? Forest Pathology. DOI: 10.1111/j.1439-0329.2011.00735.x

Davidson, JM, Werres S, Garbelotto M, Hansen EM, Rizzo DM. 2003. Sudden oak death and associated diseases caused by *Phytophthora ramorum*. Plant Health Progress doi:10.1094/PHP-2003-0707-01-DG.

Davidson, JM, Wickland AC, Patterson HA, Falk KR, Rizzo DM. 2005. Transmission of *Phytophthora ramorum* in mixed-evergreen forest in California. Phytopathology 95:587-596.

Davidson, JM, Patterson HA, Rizzo DM. 2008. Sources of Inoculum for *Phytophthora ramorum* in a redwood forest. Phytopathology 98:860-866.

Davidson, JM, Patterson HA, Wickland AC, Fichtner EJ, Rizzo DM. 2011. Forest type influences transmission of *Phytophthora ramorum* in California oak woodlands. Phytopathology 101:492-501.

EFSA Panel on Plant Health (PLH). 2011. Scientific opinion on the Pest Risk Analysis on *Phytophthora ramorum* prepared by the FP6 project RAPRA. EFSA Journal 2011;9(6):2186 [108 pp.]. doi:10.2903/j.efsa.2011.2186

Englander, L, Browning M, Tooley PW. 2006. Growth and sporulation of *Phytophthora ramorum* in vitro in response to temperature and light. Mycologia. 98:365-373.

Fichtner, EJ, Lynch SC, Rizzo DM. 2007. Detenction, distribution, sporulation, and survival of *Phytophthora ramorum* in a California redwood-tanoak forest soil. Phytopathology 97:1366-1375.

Fichtner, EJ, Rizzo DM, Webber J, KIRK SA, Whybrow A. 2010. Persistence of *Phytophthora ramorum* and *Phytophthora kernoviae* in U.K. natural areas and implications for North American forests. Pages 83-84 in: Proceedings of the Sudden Oak Death Fourth Science Symposium (S.J. Frankel, J.T. Kliejunas, K. M. Palmieri, tech. coords.) Gen. Tech. Rep. PSW-GTR-229. U.S. Dept. of Agriculture, Forest Service, Pacific Southwest Res. Station, Albany, CA.

Fichtner, EJ, Lynch SC, Rizzo DM. 2009. Survival, dispersal, and potential soil-mediated suppression of *Phytophthora ramorum* in a California redwood-tanoak forest. Phytopathology 99:608-619.

Fichtner, EJ, Rizzo DM, Kirk SA, Webber JF. 2011. Root infections may challenge management of invasive *Phytophthora* spp. in U.K. Woodlands. Plant Disease 95:13-18.

Frankel, SJ. 2008. Sudden oak death and *Phytophthora ramorum* in the USA: a management challenge. Australasian Plant Pathology 37(1):19–25.

Frankel, SJ, Kliejunas JT, Palmieri KM, tech. coords. 2008. Proceedings of the sudden oak death third science symposium. Gen. Tech. Rep. PSW-GTR-214. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA. 491 pp.

Frankel, SJ, Kliejunas JT, Palmieri KM, tech. coords. 2010. Proceedings of the Sudden Oak Death Fourth Science Symposium. Gen. Tech. Rep. PSW-GTR-229. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA. 378 pp.

Frankel, SJ, Shea, PJ, Haverty, MI, tech. coords. 2006. Proceedings of the sudden oak death second science symposium: the state of our knowledge. Gen. Tech. Rep. PSW-GTR-196. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA. 571pp.

Garbelotto, M, Davidson J, Ivors K, Maloney P, Hüberli D, Koike S, Rizzo D. 2003. Non-oak native plants are main hosts for sudden oak death pathogen in California. California Agriculture 57(1):18-23.

Garbelotto, M, Harnik TY, Schmidt DJ. 2009. Efficacy of phosphonic acid, metalaxyl-M and copper hydroxide against *Phytophthora ramorum* in vitro and in planta. Plant Pathology. 58:111–119.

Garbelotto, MM, Schmidt DJ. 2009. Phosphonate controls sudden oak death pathogen for up to two years. California Agriculture 63(1):10-17.

Goss, EM, Larsen M, Chastagner GA, Givens DR, Grünwald NJ. 2009. Population genetic analysis infers migration pathways of *Phytophthora ramorum* in US nurseries. PLoS Pathogens 5:e1000583. doi:10.1371/journal.ppat.1000583

Goss, EM, Larsen M, Vercauteren A, Werres S, Heungens K, Grünwald NJ. 2011. *Phytophthora ramorum* in Canada: evidence for migration within North America and from Europe. Phytopathology 101:166-171.

Grünwald, NJ, Goss EM, Press CM. 2008. *Phytophthora ramorum*: a pathogen with a remarkably wide host range causing sudden oak death on oaks and ramorum blight on woody ornamentals. Molecular Plant Pathology 9:729–740.

Grünwald, NJ, Goss EM, Ivors K, Garbelotto M, Martin FN, Prospero S, Hansen E, Bonants PJM, Hamelin RC, Chastagner G et al. 2009. Standardizing the nomenclature for clonal lineages of the sudden oak death pathogen, *Phytophthora ramorum*. Phytopathology 99:792-795.

Grunwald, NJ, Martin FN, Larsen MM, Sullivan CM, Press CM, Coffey MD, Hansen EM, Parke JL. 2011. Phytophthora-ID.org: a sequence-based *Phytophthora* identification tool. Plant Disease 95:337-342.

Hansen, EM, Parke JL, Sutton W. 2005. Susceptibility of Oregon forest trees and shrubs to *Phytophthora ramorum*: a comparison of artificial inoculation and natural infection. Plant Disease 89:63-70.

Hansen, EM, Kanaskie A, Prospero S, McWilliams M, Goheen EM, Osterbauer N, Reeser P, Sutton W. 2008. Epidemiology of *Phytophthora ramorum* in Oregon tanoak forests. Canadian Journal of Forest Research. 38:1133-1143.

Hayden, KJ, Rizzo D, Tse J, Garbelotto M. 2004. Detection and quantification of *Phytophthora ramorum* from California forests using a real-time polymerase chain reaction assay. Phytopathology 94(10):1075-1083.

Hayden, KJ, Nettel A, Dodd RS, Garbelotto M. 2011. Will all the trees fall? Variable resistance to an introduced forest disease in a highly susceptible host. Forest Ecology and Management 261:1781-1791.

Ireland, KB, Hüberli D, Dell B, Smith IW, Rizzo DM, Hardy SGEJ. 2011. Potential susceptibility of Australian flora to a NA2 isolate of *Phytophthora ramorum* and pathogen sporulation potential. Forest Pathology DOI: 10.1111/j.1439-0329.2011.00755.x

Kanaskie, A, Hansen EM, Goheen EM, Osterbauer N, McWilliams M, Laine J, Thompson M, Savona S, Timeus H, Woosley B et al. 2010. Detection and eradication of *Phytophthora ramorum* from Oregon forests, 2001–2008. Pages 3-5 in: Proceedings of the Sudden Oak Death Fourth Science Symposium (S.J. Frankel, J.T. Kliejunas, K. M. Palmieri, tech. coords.) Gen. Tech. Rep. PSW-GTR-229. U.S. Dept. of Agriculture, Forest Service, Pacific Southwest Res. Station, Albany, CA.

Kliejunas, JT. 2010. Sudden oak death and *Phytophthora ramorum*: a summary of the literature. Gen. Tech. Rep. PSW-GTR-234. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 181 pp.

Martin, FN, Tooley PW. 2003. Phylogenetic relationships of *Phytophthora ramorum*, *P. nemorosa*, and *P. pseudosyringae*, three species recovered from areas in California with sudden oak death. Mycological Research 107:1379–1391.

Martin, FN, Bensasson D, Tyler, BM, Boore JL. 2007. Mitochondrial genome sequences and comparative genomics of *Phytophthora ramorum* and *P. sojae*. Current Genetics 51(5): 285-296. DOI: 10.1007/s00294-007-0121-6

Mascheretti, S, Croucher PJP, Vettraino VA, Prospero S, Garbelotto M. 2008. Reconstruction of the Sudden Oak Death epidemic in California through microsatellite analysis of the pathogen *Phytophthora ramorum*. Molecular Ecology 17:2755–2768.

Meentemeyer, RK, Cunniffe NJ, Cook AR, Filipe JAN, Hunter RD, Rizzo DM, Gilligan CA. 2011. Epidemiological modeling of invasion in heterogeneous landscapes: spread of sudden oak death in California (1990–2030). Ecosphere. 2:art17. doi:10.1890/ES10-00192.1

Moralejo, E, Puig M, Garcia JA, Descals E. 2006. Stromata, sporangiomata and chlamydosori of *Phytophthora ramorum* on inoculated Mediterranean woody plants. Mycological Research 110:1323-1332.

Moralejo, E, Descals E. 2011. Diplanetism and microcyclic sporulation in *Phytophthora ramorum*. Forest Pathology 41:349–354.

Nagle, AM, Mcpherson BA, Wood DL, Garbelotto M, Bonello P. 2011. Relationship between field resistance to *Phytophthora ramorum* and constitutive phenolic chemistry of coast live oak. Forest Pathology 41:464–469.

Noble, R, Blackburn J, Thorp G, Dobrovin-Pennington A, Pietravalle S, Kerins G, Allnutt TR, Henry CM. 2011. Potential for eradication of the exotic plant pathogens *Phytophthora kernoviae* and *Phytophthora ramorum* during composting. Plant Pathology 60:1077–1085.

Osterbauer, NK, Griesbach JA, Hedberg J. 2004. Surveying for and eradicating *Phytophthora ramorum* in agricultural commodities. Plant Health Progress doi:10.1094/PHP-2004-0309-02-RS.

Parke, JL, Oh E, Voelker S, Hansen EM, Buckles G, Lachenbruch B. 2007. *Phytophthora ramorum* colonizes tanoak xylem and is associated with reduced stem water transport. Phytopathology 97:1558-1567.

Parke, JL, Lucas S. 2008. Sudden oak death and ramorum blight. The Plant Health Instructor DOI: 10.1094/PHI-I-2008-0227-01

Parke, JL, Grünwald NJ, Lewis C, Fieland V. 2010. A systems approach for detecting sources of *Phytophthora contamination* in nurseries. Pages 67-68 in: Proceedings of the Sudden Oak Death Fourth Science Symposium (S.J. Frankel, J.T. Kliejunas, K. M. Palmieri, tech. coords.) Gen. Tech. Rep. PSW-GTR-229. U.S. Dept. of Agriculture, Forest Service, Pacific Southwest Res. Station, Albany, CA.

Parke, JL, Pscheidt J, Regan R, Hedberg J, Grünwald NJ. 2010. The *Phytophthora* online course: training for nursery growers. Page 355 in: Proceedings of the Sudden Oak Death Fourth Science Symposium (S.J. Frankel, J.T. Kliejunas, K. M. Palmieri, tech. coords.) Gen. Tech. Rep. PSW-GTR-229. U.S. Dept. of Agriculture, Forest Service, Pacific Southwest Res. Station, Albany, CA.

Pérez-Sierra, A, Álvarez LA, Vercauteren A, Heungens K, Abad-Campos P. 2011. Genetic diversity, sensitivity to phenylamide fungicides and aggressiveness of *Phytophthora ramorum* on Camellia, Rhododendron and Viburnum plants in Spain. Plant Pathology 60:1069–1076.

Reeser, P, Sutton W, Hansen EM. 2008. *Phytophthora* species associated with stem cankers on tanoak in southwestern Oregon. Pages 227-229 in: Proceedings of the Sudden Oak Death Third Science Symposium (SJ Frankel, JT Kliejunas, and KM Palmieri, tech. coords.). Gen. Tech. Rep. PSW-GTR-214. U.S. Department of Agriculture, Forest Service, Forest Service, Pacific Southwest Research Station, Albany, CA.

Riley, KL, Chastagner GA, Blomquist C. 2011. First report of *Phytophthora ramorum* infecting grand fir in California. Plant Health Progress 10.1094/PHP-2011-0401-01-BR

Rizzo, DM, Garbelotto M, Davidson JM, Slaughter GW, Koike ST. 2002. *Phytophthora ramorum* as the cause of extensive mortality of Quercus spp. and Lithocarpus densiflorus in California. Plant Disease 86:205-214.

Rizzo, DM, Garbelotto M, Hansen EM. 2005. *Phytophthora ramorum*: integrative research and management of an emerging pathogen in California and Oregon forests. Annual Review of Phytopathology 43:309-335.

Sansford, CE, Inman AJ, Baker R, Brasier C, Frankel S, de Gruyter J, Husson C, Kehlenbeck H, Kessel G, Moralejo E et al.. 2009. Report on the risk of entry, establishment, spread and socio-economic loss and environmental impact and the appropriate level of management for *Phytophthora ramorum* for the EU. EU Sixth Framework Project RAPRA Deliverable Report 28. 311p.

Shea, PJ and Standiford, RB. 2002. Sudden Oak Death, a Science Symposium: The State of Our Knowledge. Dec. 17-18, 2002, Monterey, CA. Abstracts. 98 pp.

Shishkoff, N. 2011. A test system to quantify inoculum in runoff from *Phytophthora ramorum*-infected plant roots. Phytopathology 101(12):1457-1464.

Swiecki, TJ, Bernhardt E. 2008. Increasing distance from California bay reduces the risk and severity of *Phytophthora ramorum* canker in coast live oak. Pages 181-194 in: Proceedings of the Sudden Oak Death Third Science Symposium (SJ Frankel, JT Kliejunas, and KM Palmieri, tech. coords.). Gen. Tech. Rep. PSW-GTR-214. U.S. Department of Agriculture, Forest Service, Forest Service, Pacific Southwest Research Station, Albany, CA.

Tooley, PW, Carras MM. 2011. Enhanced Recovery of

Phytophthora ramorum

from soil following 30 days of storage at 4°C. Journal of Phytopathology 159:641-643.

Tyler, BM, Tripathy S, Zhang X, Dehal P, Jiang RHY, Aerts A, Arredondo FD, Baxter L, Bensasson D, Beynon JL et al.. 2006. *Phytophthora* genome sequences uncover evolutionary origins and mechanisms of pathogenesis. Science 313:1261-1266.

Valachovic, Y, Lee C, Marshall J, Scanlon H. 2008. Wildland management of *Phytophthora ramorum* in northern California forests. Pages 305-312 in: Proceedings of the Sudden Oak Death Third Science Symposium (SJ Frankel, JT Kliejunas, and KM Palmieri, tech. coords.). Gen. Tech. Rep. PSW-GTR-214. U.S. Department of Agriculture, Forest Service, Forest Service, Pacific Southwest Research Station, Albany, CA.

Valachovic, Y, C. Lee MJ, Scanlon H. 2010. Forest treatment strategies for *Phytophthora ramorum*. Pages 239-248 in: Proceedings of the Sudden Oak Death Fourth Science Symposium (S.J. Frankel, J.T. Kliejunas, K. M. Palmieri, tech. coords.) Gen. Tech. Rep. PSW-GTR-229. U.S. Dept. of Agriculture, Forest Service, Pacific Southwest Res. Station, Albany, CA.

Werres, S, Marwitz R, veld WMI'tA, Cock ADWAM, Bonants PJM, Weerdt MD, Themann K, Ilieva E, Baayen RP. 2001. *Phytophthora ramorum* sp. nov., a new pathogen on Rhododendron and Viburnum. Mycological Research 105:1155-1165.

Yakabe, LE, Blomquist CL, Thomas SL, MacDonald JD. 2009. Identification and frequency of *Phytophthora* species associated with foliar diseases in California ornamental nurseries. Plant Disease 93:883-890.