Phytophthora ramorum: susceptibility of Australian plants, potential geographic range and science into policy and management

by

Kylie Belle Ireland
BA BSc (Hons), *Qld*.

Submitted in fulfilment of the requirements for the
Degree of Doctor of Philosophy

School of Biological Sciences and Biotechnology
Murdoch University, Perth, Western Australia

Submitted August 2011
Awarded February 2012

DECLARATION

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted to a degree or diploma at any tertiary education institution.

Kylie Ireland

ABSTRACT

Phytophthora ramorum is an invasive plant pathogen causing considerable and widespread damage in nurseries, gardens and natural woodland ecosystems of the USA and Europe. In Australia, where it is classified as a Category 1 emergency plant pest, it has the potential to become a major economic and ecological threat in areas with susceptible hosts and a favourable climate. *Phytophthora ramorum* causes three distinct diseases on susceptible plants: ramorum leaf blight, ramorum shoot dieback and sudden oak death (characterised by lethal bole cankers). In some species, foliar infection can play a crucial role in disease development by producing inoculum that can drive an epiphytotic. The geographic origin of *P. ramorum* remains unknown and an understanding of the environmental requirements most conducive to establishment and persistence of disease under natural conditions is still poorly understood. This study aimed to: (a) provide an understanding of the foliar, branch and bole susceptibility to *P. ramorum* and sporangia producing potential of a broad range of Australian plant species; (b) develop a climate-based model of the potential geographic range of the pathogen; and (c) analyse the effectiveness of integration of scientific knowledge between European and North American policy and management responses to *P. ramorum*.

Detached leaves, branches and logs of up to 70 Australian native plant species were tested for their susceptibility and sporulation potential. Foliar susceptibility was tested using detached leaf assays for 70 Australian native plant species; twenty-eight of these species were tested for their ability to produce sporangia on foliage. Branch dieback susceptibility was tested for 66 of these species, six of which were further tested for their susceptibility to bole cankers caused by *P. ramorum* using a sealed log assay. All materials were sourced from native woodlands, established gardens and arboreta in California. Positive control species known to be naturally highly susceptible to *P. ramorum* were included in all experiments.

All species tested were capable of being infected by *P. ramorum*. Highly susceptible foliar hosts included *Banksia attenuata*, *Eucalyptus delegatensis*, *E. denticulata*, *E. viminalis*, *Isopogon cuneatus*, *I. formosus* and *Leptospermum scoparium*. *Hedycarya angustifolia*, *Olearia argophylla*, *Phyllocladus aspleniifolius*, *Pittosporum undulatum* and *Podocarpus lawrencei*

were identified as potentially resistant foliar hosts. Putative sporulating hosts include five members of the Myrtaceae: *Agonis flexuosa, C. ficifolia, E. haemastoma, E. delegatensis* and *E. viminalis.* Highly susceptible branch hosts included *E. denticulata*, *E. sideroxylon*, *E. viminalis*, *Hardenbergia violaceae*, *I. formosus* and *N. cunninghamii*. Thirteen potentially tolerant branch dieback hosts were identified and included *B. attenuata*, *B. marginata*, *Billardiera heterophylla*, *E. haemastoma*, *E. regnans* and *P. undulatum*. *Eucalyptus regnans* was identified as a potentially highly susceptible bole canker host, while *E. diversicolor* and *E. viminalis* were considered potentially tolerant species to bole cankers caused by *P. ramorum*.

A simulation model was developed using CLIMEX to estimate the global climate suitability patterns for establishment of *P. ramorum*. Growth requirements and stress response parameters were derived from ecophysiological laboratory observations and site-level transmission and disease factors related to climate data in the field. Models fitted to the European (EU1) and combined EU1 and North American (NA1) genotypes indicated that European genotypes may be constrained to a greater degree by higher temperatures than North American genotypes. The combined risk model suggests that the invasion of *P. ramorum* in both North America and Europe is still in its infancy and it is presently occupying a small fraction of its available range. Southern Europe may be at greater risk of invasion should the NA1 genotype be introduced into warmer areas unsuitable for the predominant EU1 genotype. *Phytophthora ramorum* appears to be climatically suited to large areas of Australasia (including New Zealand), Africa and South America. Potential distribution in Australia indicates south east coastal Australia, the southwest region of Western Australia and Tasmania are at highest risk of invasion.

Comparison of the integration of science into policy-making and control efforts in Europe and North America are varied, representing the use of many different ‘boundary arrangements’. Experiences with *P. ramorum* in these regions indicate that future biosecurity efforts to prevent the entry and establishment of *P. ramorum* and other invasive organisms may benefit from: (i) fostering local management approaches which connect and build relationships with affected communities and build capacity accordingly; (ii) incorporating structural arrangements for the integration of science into policy at a national level, encouraging scientists and policy makers to directly engage with one-another to allow for the rapid dissemination of new knowledge directly applicable to policy applications; (iii) aiming to produce regional or global pest risk analyses which enable knowledge and research cost-sharing, and; (iv) investment in studies outlining the effectiveness and success of different boundary arrangements in achieving positive biosecurity outcomes.

These results extend the known potential host range for *P. ramorum* and define its potential geographic range, confirming it as a potential threat to Australian plant industries and ecosystems. Caution is advised when interpreting these results; the species studied represent only a small proportion of Australian taxa which exist in climatically suitable areas for the pathogen in Australia and invasive organisms may behave differently in novel locations given different environmental and management constraints. Nevertheless, risk predictions generated by the model, an understanding of the pathogen's potential host range and analysis of the best way to integrate this knowledge into policy and management efforts will allow us to target high risk areas for early detection surveillance and assist Australian regulators in developing appropriate quarantine policies and protocols.

ACKNOWLEDGEMENTS

Many thanks to my supervisors - Prof. Giles Hardy, Dr Daniel Hüberli, Prof. Bernie Dell and Mr Ian Smith. Under your direction I have grown as a plant pathologist. Giles and Daniel, thank you for having the foresight to initiate and direct such a unique project and for facilitating my integration into the forest *Phytophthora* community. Ian, you were also instrumental in making me feel welcome in the forest *Phytophthora* community and were of invaluable support in lending your time and expertise as you entered retirement. I am particularly grateful to you for the two weeks of hard labour you endured in order to allow me to finish the log inoculation work so quickly. I am grateful to all of my supervisors for thoroughly reviewing all of my work.

My heartfelt thanks goes to Prof. David Rizzo, the Rizzo lab and the extended Rizzo lab family who welcomed me wholeheartedly and allowed me to conduct my research in their lab and as a part of their lives at the University of California Davis. Kamyar Aram, Andrea Brauer, Richard Cobb, Dr Elizabeth Fichtner, Shannon Lynch, Heather Mehl, Dr Margaret Metz, Christine Shoemaker, Sarah Navarro, Akiko Oguchi and Lottie White were much more than lab mates, providing crucial emotional support and friendship during my time abroad. Laurana Snyder and Michael Jones, I am forever in your debt, you were the best help I could ever have imagined. Without the continued assistance of Michael this work would not have been completed so easily. I am also grateful to Wendy Johnson-Mesa of the plant pathology administration for facilitating all of my official paperwork and accounts at UC Davis.

Many thanks for the great friendship and support given to me through the Centre for *Phytophthora* Science and Management at Murdoch University and the broader Hardy group. To my fellow students, thanks so much for coffee time and friendship, especially Monique Sakalidis, Amy Smith and Rebecca Zappia. I wouldn’t have survived without our coffee breaks - thanks for so often finding the time, even if you didn’t need the caffeine yourself!

I am indebted to Dr Darren Kriticos for being so thoroughly patient in sharing his expertise in pest risk mapping and helping me to build the CLIMEX model presented here. Darren aided in laying to rest my fears of the uncertainties of modelling and I now embrace them as a part of the process, which I believe has made me a better scientist. Thank you also for introducing me to the wonderful people who form part of the international pest risk mapping group, I am thankful to them also for being so warm and welcoming. In this vein I would also like to thank A. Kanaskie, R. Meentemeyer, T. Rafoss, A. Rytkönen and T. Václavík for assistance with obtaining point location data for *P. ramorum* to help validate the model.

I wish also to thank the community of forest *Phytophthora* researchers who have had invaluable input into the direction, methodology and collation of resources for this project. Thanks in particular go to Susan Frankel of the USDA Forest Service, Sandra Denman and Joan Webber of Forest Research UK and all of those who contributed to the formulation of my host species "wish list".

This project would not have been possible without the plant material kindly supplied by the Midpenisula Regional Open Space District, UC Berkeley Botanical Garden, UC Davis Arboretum, UC Santa Cruz Arboretum and the San Francisco Strybing Arboretum. I am particularly thankful to Melinda Kralj and Brett Hall of the UC Santa Cruz Arboretum who helped me to navigate Light Brown Apple moth quarantine and obtain so much crucial material for my studies – I enjoyed working in the beauty of your garden.

I would like to acknowledge the support of the Australian Government's Cooperative Research Centres Program and the Department of Sustainability, Environment, Water, Population and Communities. This project would not have been possible without the enduring support of the Cooperative Research Centre for National Plant Biosecurity. I am thankful for all the opportunities that being a part of the CRC has afforded me, particularly in being able to forge friendships and international collaborative relationships with fellow students and scientists in the field of plant biosecurity.

Finally, thank you so much to my friends, family and flat-mates (in Australia and the USA) for your enduring support. I have grown not only as a scientist in these past four years, but also as a person, and I have you to thank for your love and encouragement in achieving that. To my partner Gavin, I look forward to being a different person without the "thesis" and words can't express how much your love and support has buoyed me as I've completed this beast.

CONTENTS

LIST OF ABBREVIATIONS

AL	Alabama
ANOVA	Analysis of Variance
APHIS	Animal and Plant Health Inspection Service
APPPC	Asia and Pacific Plant Protection Commission
AQIS	Australian Quarantine and Inspection Service
ARS	Agricultural Research Service
AVH	Australia's Virtual Herbarium
BA	Biosecurity Australia
BC	British Columbia
CA	California
CDF	Californian Department of Forestry and Fire Protection
CDFA	Californian Department of Food and Agriculture
CDX	Cold-Dry Stress
CFIA	Canadian Food Inspection Agency
CFPC	California Forest Pest Council
COMTF	California Oak Mortality Task Force, USA
CPHST	Centre for Plant Health Science and Technology
CRC NPB	Cooperative Research Centre for National Plant Biosecurity
CRC NPB	Cooperative Research Centre for National Plant Biosecurity
CS	Cold Stress
cv.	cultivar
CWX	Cold-Wet Stress
DE	Delaware
DEFRA	Department for Environment, Food and Rural Affairs
Dept. of Ag.	Department of Agriculture
DIG	Dieback Information Group
DIUS	Department for Innovation, Universities and Skills
DPI	Department of Primary Industries (with primary reference to Australian state agencies)
DS	Dry Stress
DTI	Department for Trade and Industry
EPPO	European and Mediterranean Plant Protection Organisation
EI	Ecoclimatic Index
EU	European Union
EU1	*Phytophthora ramorum* European genotype 1
FAO	Food and Agriculture Organisation

FERA	Food and Environment Research Agency, UK
FL	Florida
GA	Georgia
GH	Glasshouse
GI_A	Annual Growth Index
HDX	Hot-Dry Stress
HWX	Hot-Wet Stress
HM	Her Majesty's
HS	Hot Stress
IMEDEA	Instudio Mediterraneo de Estudios Avanzados (Mediterranean Institute of Advanced Studies)
IN	Indiana
INRA	National Institute for Agricultural Research
IPPC	International Plant Protection Convention
ISPM	International Standards for Phytosanitary Measures
KY	Kentucky
LA	Louisiana
MI	Moisture Index
MS	Mississippi
MT	Montana
NA1	*Phytophthora ramorum* North American genotype 1
NA2	*Phytophthora ramorum* North American genotype 2
NAFTA	North American Free Trade Agreement
NAPPO	North American Plant Protection Organisation
NJ	New Jersey
ODA	Oregon Department of Agriculture
OR	Oregon
OSU	Oregon State University
PCR	Polymerase Chain Reaction
PHA	Plant Health Australia
PHQuads	Plant Health Quadrilaterals
PPQ	Plant Health, Plant Protection and Quarantine
PRA	Pest Risk Analysis/Assessment
RAPRA	Risk Analysis for *Phytophthora ramorum*
SCWG	Scientific Collaboration Working Group (PHQuads)
SFBG	San Francisco Botanical Gardens
SI	Stress Index
SOD	Sudden Oak Death

SPS	Sanitary and Phytosanitary Measures
SX	Stress Interaction Index
TGI	Thermo-hydrological Growth Index
TI	Temperature Index
TN	Tennessee
UC	University of California
UCB	University of California, Berkeley
UCD	University of California, Davis
UCSC	University of California, Santa Cruz
UK	United Kingdom
US	United States (of America)
USA	United States of America
USDA	United States Department of Agriculture
USFS	United States Forest Service
UT	Utah
VA	Virginia
WA	Washington
WMO	World Meteorological Organisation
WS	Wet Stress
WV	West Virginia
ZOI	Zone of Infestation

LIST OF PLANT SPECIES

Australian species included in experiments

Species	Common name(s)	Synonym/parent species	Family
Acacia dealbata	Silver wattle		Mimosaceae
Acacia melanoxylon	Blackwood		Mimosaceae
Acmena smithii	Lilly pilly		Myrtaceae
Adenanthos obovatus	Jug flower		Proteaceae
Agonis flexuosa	Willow myrtle		Myrtaceae
Atherosperma moschatum	Southern sassafras		Monomiaceae
Banksia attenuata	Slender banksia		Proteaceae
Banksia marginata	Silver banksia		Proteaceae
Bauera rubioides	Dog rose; River rose		Baueraceae
Billardiera heterophylla	Blue-bell creeper	*Sollya heterophylla*	Pittosporaceae
Brachychiton populneus	Kurrajong		Sterculiaceae
Bursaria spinosa	Blackthorn; Sweet Bursaria		Pittosporaceae
Callitris rhomboidea	Port Jackson Pine		Cupressaceae
Ceratopetalum apetalum	Coachwood		Cunoniaceae
Correa alba	White correa		Rutaceae
Correa backhousiana	Velvet correa		Rutaceae
Correa decumbens			Rutaceae
Correa cv. Ivory Bells	Correa	*Correa alba* x *C. backhousiana*	Rutaceae

Correa reflexa	Common correa; native fuchsia		Rutaceae
Correa cv. Sister Dawn			Rutaceae
Corymbia ficifolia	Red-flowering gum	*Eucalyptus ficifolia*	Myrtaceae
Corymbia maculata	Spotted gum	*Eucalyptus maculata*	Myrtaceae
Dicksonia antarctica	Soft tree fern		Dicksoniaceae
Dodonea viscosa	Sticky hop bush		Sapindaceae
Eucalyptus camaldulensis	River red gum		Myrtaceae
Eucalyptus cneorifolia		*Eucalyptus myrtiformis, E. hypericifolia*	Myrtaceae
Eucalyptus delegatensis	Alpine ash; Woolybutt		Myrtaceae
Eucalyptus denticulata	Errinundra Shining Gum	*Eucalyptus* sp. aff. *nitens* (Errinundra)	Myrtaceae
Eucalyptus diversicolor	Karri		Myrtaceae
Eucalyptus globulus	Tasmanian blue gum		Myrtaceae
Eucalyptus haemastoma	Scribbly gum		Myrtaceae
Eucalyptus laeliae	Darling Range ghost gum		
Eucalyptus leucoxylon	Yellow gum		Myrtaceae
Eucalyptus pauciflora	Snow gum		Myrtaceae
Eucalyptus regnans	Mountain ash		Myrtaceae
Eucalyptus saligna	Sydney blue gum		Myrtaceae
Eucalyptus sideroxylon	Red ironbark		Myrtaceae
Hakea rostrata	Beaked pincushion tree		Proteaceae
Hardenbergia violaceae	Native sarsaparilla; Purple coral pea		Papilionaceae
Hedycarya angustifolia	Austral mulberry		Monomiaceae

Australian species included in experiments (continued)

Species	Common name(s)	Synonym/parent species	Family
Isopogon cuneatus	Coneflower		Proteaceae
Isopogon formosus	Rose cone flower		Proteaceae
Lagarostrobos franklinii	Huon pine'; Macquarie pine	*Dacrydium franklinii*	Podocarpaceae
Leptospermum grandiflorum	Mountain tea tree		Myrtaceae
Leptospermum lanigerum	Silky tea tree		Myrtaceae
Leptospermum scoparium	Manuka		Myrtaceae
Lomandra longifolia	Spiny-head mat-rush; Basket grass		Asparagaceae
Lomatia myricoides	Long-leaf lomatia		Proteaceae
Macadamia tetraphylla			Proteaceae
Melaleuca squamea	Swamp honey-myrtle		Myrtaceae
Nothofagus cunninghamii	Myrtle beech		Fagaceae
Nothofagus moorei	Antarctic beech		Fagaceae
Olearia argophylla	Native musk; Silver shrub		Asteraceae
Phyllocladus aspleniifolius	Celery-top pine		Podocarpaceae
Pittosporum undulatum	Sweet pittosporum; native daphne		Pittosporaceae
Podocarpus lawrencei	Mountain plum pine	*Podocarpus alpina var. lawrencei*	Podocarpaceae
Polyscias sambucifolia	Elderberry panax		Araliaceae
Pomaderris apetala	Dogwood/Hazel		Rhamnaceae
Prostanthera lasianthos	Victorian Christmas tree		Lamiaceae

Senecio linearifolius			Asteraceae
Stylidium graminifolium	Grass trigger plant		Stylidiaceae
Tasmannia lanceolata	Mountain pepper	*Drimys lanceolata*	Winteraceae
Taxandria marginata	Arnica	*Agonis marginata*	Myrtaceae
Tristaniopsis laurina	Kanooka	*Tristania laurina*	Myrtaceae
Viola hederaceae	Native violet; Ivy-leaved violet		Violaceae
Xanthorrhoeae australis	Grass tree		Xanthorrhoeaceae
Xanthorrhoea preisii	Grass tree		Xanthorrhoeaceae
Control species included in experiments			
Notholithocarpus densiflorus	Tanoak	*Lithocarpus densiflorus*	Fagaceae
Rhododendron cv. Colonel Coen			Ericaceae
Umbellularia californica	California bay laurel; Oregon myrtle		Lauraceae

PREFACE

This Ph.D. thesis is composed of three papers which have been submitted for publication to refereed international journals and a final thesis chapter intended for future publication. To enhance the structure the thesis, the following changes have been made:

- References been removed and aggregated to a single list of references at the end of the thesis;
- Abstracts and acknowledgements have been removed;
- Cross-references to papers and supplementary material within the thesis have been changed to refer to chapter number or appendix;
- Abbreviations are cited at the earliest point in the thesis and generally not repeated and a list of abbreviations is provided;
- Species are shortened after first mentioned and a list of plant species included in the studies provided.

Publications arising from this project are as follows and early online editions published after the submission of the thesis are appended in Appendix D:

REFEREED JOURNAL PAPERS

Chapter 2: Ireland, K.B., D. Hüberli, B. Dell, I.W. Smith, D.M. Rizzo and G.E.St J. Hardy (Online). "Potential susceptibility of Australian native flora to NA2 isolate of *Phytophthora ramorum* and pathogen sporulation potential." *Forest Pathology*. doi: 10.1111/j.1439-0329.2011.00755.x

Chapter 3: Ireland, K.B., D. Hüberli, B. Dell, I.W. Smith, D.M. Rizzo and G.E.St J. Hardy (Online). "Potential susceptibility of Australian native plant species to branch dieback and bole canker diseases of *Phytophthora ramorum*." *Plant Pathology*. doi: 10.1111/j.1365-3059.2011.02513.x

All of these publications are my own work (> 90 %), based on experiments planned and conducted by myself under academic supervision. Supervisors contributed through acquiring funds for the project and outlining the initial project proposal, which I then altered to bring about my own research directive. All co-authors contributed to editing of the papers they were on.

Roles of co-authors are as follows:

Prof. Bernard Dell (Chapter 2 and 3): Co-supervisor through Murdoch University.

Prof. Giles E. St J. Hardy (Chapters 2, 3 and 4): Primary supervisor through Murdoch University.

Dr Daniel Hüberli (Chapter 2 and 3): Co-supervisor through Murdoch University.

Mr Ian W. Smith (Chapter 2 and 3): Co-supervisor and collaborator from the University of Melbourne.

Prof. David M. Rizzo (Chapter 2 and 3): Collaborator and host at the University of California, Davis.

REFEREED CONFERENCE PROCEEDINGS

Ireland, K., D. Hüberli, B. Dell, I. Smith, D. Rizzo and G.E. St J. Hardy (2009). "Susceptibility of Australian Plant Species to *Phytophthora ramorum*." In: *Proceedings of the Sudden Oak Death Fourth Science Symposium. Gen. Tech. Rep. PSW-GTR-229.* S. J. Frankel, J. T. Kliejunas and K. M. Palmieri, tech. cords. Albany, CA: U.S.A, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 202-206.

CONFERENCE PROCEEDINGS AND PRESENTATIONS

Ireland, K., D. Hüberli, B. Dell, I. Smith, D. Rizzo and G.E. St J. Hardy (2011). "Australian Native Plant Susceptibility to *Phytophthora ramorum*." *New Zealand Journal of Forestry*

Science. **41**: s20 (*Proceedings of the Fifth IUFRO Phytophthora Diseases in Natural Systems and Ecosystems Conference*, 2010, Rotorua, NZ).

Ireland, K., D. Hüberli, B. Dell, I. Smith, D. Kriticos, D. Rizzo and G.E. St J. Hardy (2011). "Sudden Eucalypt Death? Susceptibility of Australian plants to *Phytophthora ramorum* and potential global distribution." *Cooperative Research Centre for National Plant Biosecurity Science Exchange*, Barossa Valley, Australia.

Ireland, K., D. Hüberli, B. Dell, I. Smith, D. Kriticos and G.E. St J. Hardy (2010). "Australian native plant susceptibility to *Phytophthora ramorum*." *Fourth annual APPS student and early career researchers symposium*, South Perth, Australia.

Ireland, K., D. Hüberli, B. Dell, I. Smith, G.E. St J. Hardy and D. Kriticos (2010). "Modelling the potential range of a distributionally challenged pathogen -*Phytophthora ramorum.*" *Fourth meeting of the International Pest Risk Modelling Workgroup*, Port Douglas, Australia.

Ireland, K., T. Burgess and G.E. St J. Hardy (2010). "Protecting your assets: Beyond Dieback-*Phytophthora* Aware and Biosecure." *Cradle of Creation: International Plant Propagators Society of Australia Annual Conference*, Fremantle, Australia.

Ireland, K., D. Hüberli, B. Dell, I. Smith, D. Rizzo and G.E. St J. Hardy (2010). "Australian plant susceptibility to *Phytophthora ramorum* and their role in driving a potential epiphytotic." *Global Biosecurity Conference*, Brisbane, Australia.

Ireland, K., D. Hüberli, B. Dell, I. Smith, D. Rizzo and G.E. St J. Hardy (2009). "Australian host range studies of *Phytophthora ramorum*." *International Pest Risk Mapping Meeting*, Pescadero, CA, USA.

Ireland, K., D. Hüberli, B. Dell, I. Smith, D. Rizzo and G.E. St J. Hardy (2009). "Susceptibility of Australian plant species to *Phytophthora ramorum*." *Fourth Sudden Oak Death Science Symposium*, Santa Cruz, CA, USA.

Ireland, K., D. Hüberli, B. Dell, I. Smith, D. Rizzo and G.E. St J. Hardy (2009). "Susceptibility of Australian plant species to *Phytophthora ramorum.*" In*: IUFRO Forest Biosecurity*

Conference. M. Richardson, C. Hodgson and A. Forbes, Eds. Rotorua, New Zealand: New Zealand Forest Research Institute Limited: 41.

Ireland, K., D. Hüberli, B. Dell, and G.E. St J. Hardy (2007). "Terror Alert: Australasia at high risk of *Phytophthora ramorum* epidemic." *Dieback Information Group*, Fremantle, Australia.

Ireland, K., D. Hüberli, B. Dell, I. Smith, E. Fichtner, D. Rizzo and G.E. St J. Hardy (2007). "Hidden Agenda: Asymptomatic Infection and Sporulation by *Phytophthora ramorum*, a serious threat to Australian biodiversity." *CRC for National Plant Biosecurity Science Exchange*, Melbourne, Australia.

Hüberli, D., K. Ireland, I. Smith, B. Dell, D. Rizzo, M. Garbelotto and G.E. St J. Hardy (2007). "Australasia is at high risk of a *Phytophthora ramorum* epidemic." In E.M. Goheen and S. J. Frankel (tech. cords.) *Phytophthoras in Forests and Natural Ecosystems. Proceedings of the Fourth meeting of the International Union of Forest Research Organisations (IUFRO) Working Party 07.02.09. August 26-31, 2007, Monterey, Ca. Gen. Tech. Rep. PSW-GTR-221.* Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 184-187.

CONFERENCE POSTERS

Ireland, K., D. Hüberli, B. Dell, I. Smith, D. Rizzo and G.E. St J. Hardy (2009). "Australian plant susceptibility to *Phytophthora ramorum*." *CRC for National Plant Biosecurity Science Exchange*, Noosa, Australia.

Ireland, K., D. Hüberli, B. Dell, I. Smith, D. Rizzo and G.E. St J. Hardy (2009). "Australian plant susceptibility to *Phytophthora ramorum*." *University of California Davis Plant Pathology Retreat*, Davis, CA, US"