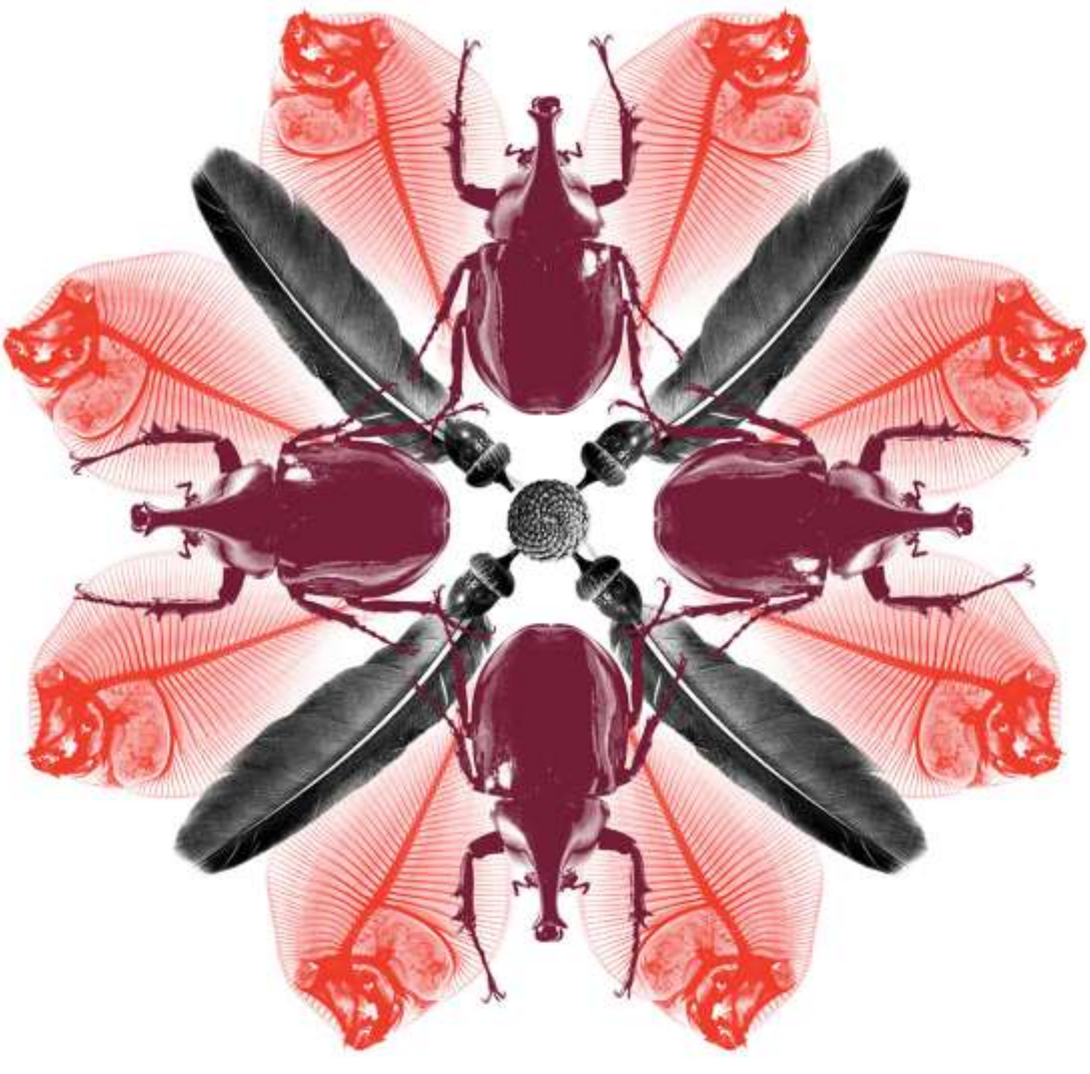
Australian Government
Department of Agriculture and Water Resources

Final review of policy: importation of *Phytophthora ramorum* host propagative material into Australia

November 2015



Cataloguing data

Department of Agriculture and Water Resources 2015, Final review of policy: importation of *Phytophthora ramorum* host propagative material into Australia. Department of Agriculture and Water Resources, Canberra.

This publication is available at agriculture.gov.au.

Australian Department of Agriculture and Water Resources

Postal address: GPO Box 858 Canberra ACT 2601

Switchboard: +61 2 6272 3933 or 1800 900 090

Facsimile: +61 2 6272 3307

Email: plant@agriculture.gov.au

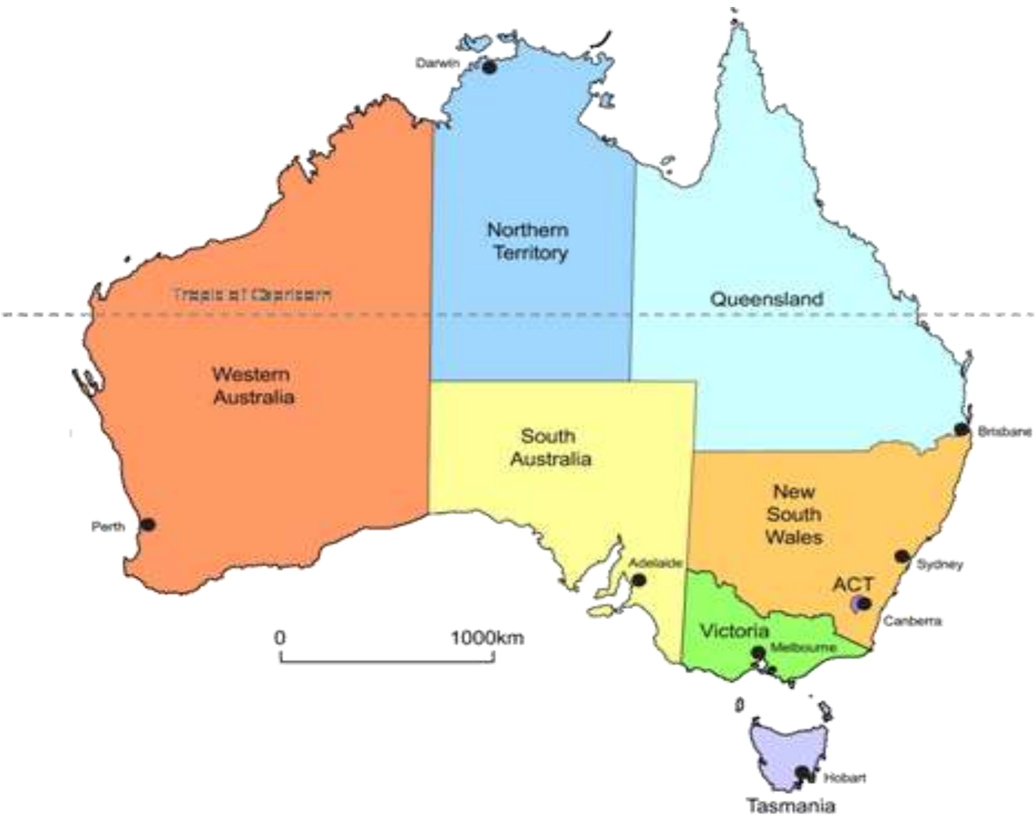
Contents

Figures

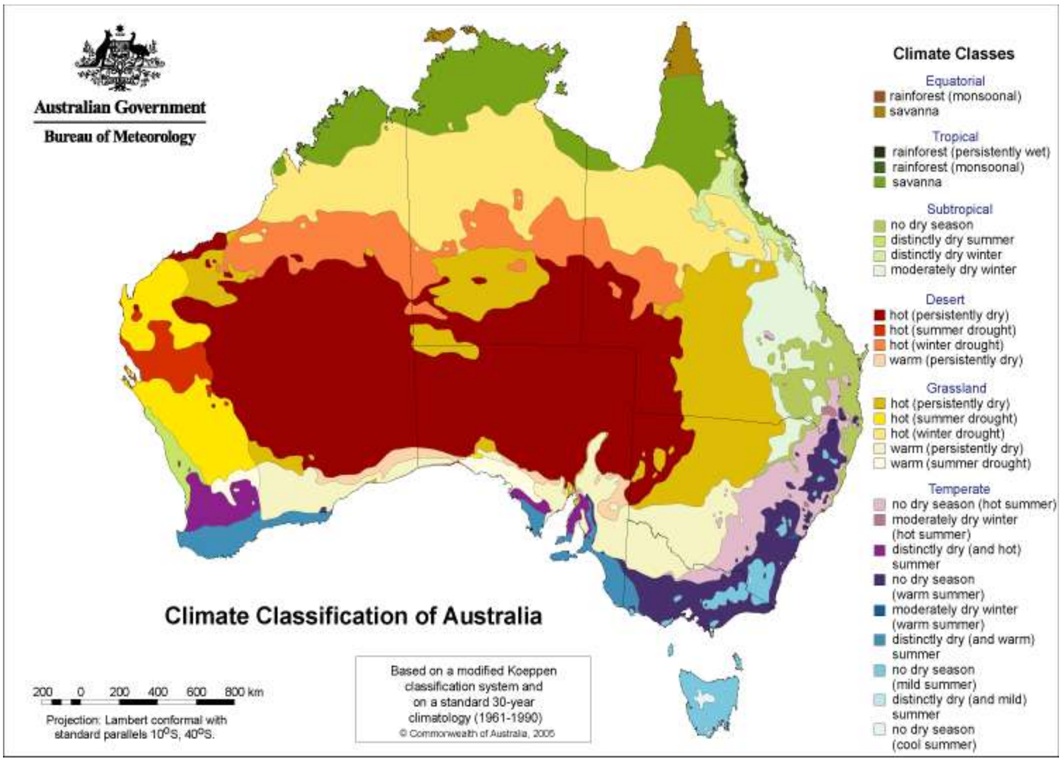
Tables

Maps

Map 1 Map of Australia



Map 2 A guide to Australia's bio-climatic zones



Acronyms and abbreviations

Term or abbreviation	Definition
ACT	Australian Capital Territory
ALOP	Appropriate level of protection
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FAO	Food and Agriculture Organization of the United Nations
ICON	The Australian Government Department of Agriculture and Water Resources Import CONditions database
IPGR	International Plant Genetic Resource
IPPC	International Plant Protection Convention
IRA	Import risk analysis
ISPM	International Standard for Phytosanitary Measures
NSW	New South Wales
NPPO	National Plant Protection Organisation
NT	Northern Territory
OIE	World Organisation for Animal Health
PEQ	Post-entry quarantine
PCR	Polymerase Chain Reaction
PRA	Pest risk anaylsis
QLD	Queensland
SA	South Australia
SOD	Sudden oak death
SPS	Sanitary and Phytosanitary
TAS	Tasmania
VIC	Victoria
WA	Western Australia
WTO	World Trade Organization

Summary

The Australian Government Department of Agriculture and Water Resources (the department) initiated this review following a request from the Australian nursery industry to revise the import conditions for host nursery stock from countries where *Phytophthora ramorum* is known to occur. The review recommends that, not only *Phytophthora ramorum* be regulated, but also *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae*. These *Phytophthora* species share a similar host range, geographic range and cause symptoms indistinguishable from those of *P. ramorum*.

The introduction of these *Phytophthora* species into Australia would have unacceptable economic consequences. *Phytophthora ramorum* is the most destructive pathogen of oak and a range of other host plants with significant commercial value, causing direct host mortality and increasing the cost of production due to its regulatory impact. The Australian nursery industry has a retail value of approximately $1.8 to $2 billion and the establishment of these *Phytophthora* species in Australia would necessitate higher levels of pathogen control in nurseries than is currently practised. Hosts of *Phytophthora* species also include many important shrubs and trees of recreational or environmental significance. If introduced, these species would be a major threat to southern Australian forest and woodland systems.

The ultimate goal of Australia's phytosanitary measures is to protect plant health and prevent the introduction of *P. ramorum, P. kernoviae*, *P. nemorosa* and *P. pseudosyringae* associated with plant propagative material into Australia. The review recommends:

- Regulating the natural hosts of *P. ramorum*, *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae* at the genus level;
- The removal of experimental hosts from the regulated host list; and
- Allowing the importation of all natural hosts of *Phytophthora* species under review as tissue cultures, one-year-old dormant cuttings, one-year-old budwood and one-year-old bare-rooted plants without foliage, as the recommended measures mitigate the risk of these *Phytophthora* species.

The recommended risk management measures for the importation of host nursery stock are based on a systems approach. Each of the recommended measures is not designed to be 'stand alone'; rather, the measures work in combination to ensure the risk is progressively reduced and managed to meet Australia's appropriate level of protection (ALOP). The department considers these measures to be the least trade restrictive, while reducing the risk of *P. ramorum, P. kernoviae, P. nemorosa* and *P. pseudosyringae* to a very low level. This review recommends the following tiered approach:

Off-shore measures to minimise risks

- Bare-rooted plants are produced in a commercial environment and inspected by the National Plant Protection Organisation (NPPO) to verify freedom from disease symptoms.
- Restricting bare-rooted plants, budwood and dormant cuttings to one-year-old material, thereby lessening the exposure of material to disease infection.

- An official Phytosanitary Certificate endorsed with an additional declaration that bare-rooted plants, dormant cuttings, budwood and tissue cultures have been inspected and found free from obvious disease symptoms.

On-shore measures to minimise risks

- On-arrival examination of bare-rooted plants, budwood and dormant cuttings for disease symptoms, treatment and growth under conditions that favour symptom expression.
- On-arrival examination of tissue cultures to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern.

On-arrival testing

- On-arrival, propagative material (bare-rooted plants, budwood and dormant cuttings) is cultured on selective culture media and tested for *Phytophthora* species using a generic Polymerase Chain Reaction (PCR).

Growth in post-entry quarantine (PEQ)

- Mandatory growth of propagative material in a closed government PEQ facility for a minimum of 12 to 15 months, with disease screening.
- During growth in PEQ, imported bare-rooted plants, dormant cuttings, budwood and tissue cultures must be subjected to molecular testing for *Phytophthora* species using a generic PCR.

The existing conditions for propagative material from countries where these *Phytophthora* species are not known to occur are recommended to continue.

The department released the 'Draft review of policy: importation of *Phytophthora ramorum* host propagative material into Australia' for stakeholder consultation for 45 days from 16 March 2015. The department received submissions from international and domestic stakeholders. All comments were carefully considered in the finalisation of this review of policy.

1. Introduction

1.1 Australia’s biosecurity policy framework

Australia's biosecurity policies aim to protect Australia against the risks that may arise from exotic pests entering, establishing and spreading in Australia, thereby threatening Australia's unique flora and fauna, as well as those agricultural industries that are relatively free from serious pests.

The risk analysis process is an important part of Australia's biosecurity policies. It enables the Australian Government to formally consider the risks that could be associated with proposals to import new products into Australia. If the risks are found to exceed Australia’s appropriate level of protection (ALOP), risk management measures are proposed to reduce the risks to an acceptable level. But, if it is not possible to reduce the risks to an acceptable level, then no trade will be allowed.

Successive Australian governments have maintained a stringent, but not a zero risk approach to the management of biosecurity risks. This approach is expressed in terms of Australia's ALOP, which reflects community expectations through government policy and is currently described as providing a high level of protection aimed at reducing risk to a very low level, but not to zero.

Australia’s pest risk analyses (PRAs) are undertaken by the Department of Agriculture and Water Resources, hereafter referred to as the department, using teams of technical and scientific experts in relevant fields and involves consultation with stakeholders at various stages during the process.

Further information about Australia’s biosecurity framework is provided in Appendix C of this report and in the *Import Risk Analysis Handbook 2011* located on the Department of Agriculture and Water Resources website.

1.2 This review of policy

Australia has an existing policy to import *Phytophthora ramorum* host propagative material from all countries. Until recently, propagative material was only allowed as tissue cultures (microplantlets) from countries where *P. ramorum* is known to occur. Imported tissue cultures require mandatory on-arrival inspection and growth in a closed post-entry quarantine (PEQ) facility with pathogen screening.

1.2.1 Background

Australia introduced emergency measures in September 2002 after the identification and description of *Phytophthora ramorum* as the causal agent of Sudden oak death (SOD) in the United States of America (USA), and Ramorum blight of ornamentals including *Rhododendron* and *Viburnum* species in Europe (Werres et al. 2001). At this time, the importation of *P. ramorum* host material from countries where the pathogen is known to occur was restricted to tissue cultures only. The implementation of these measures effectively prohibited imports of host material that cannot be easily propagated through tissue cultures from countries where *P. ramorum* is present. This policy was generally supported and accepted by industry as the pathogen was newly described, its epidemiology was unknown, no reliable detection method was available and the economic consequences of the pathogen were high.

In 2013, the department revised the import conditions for a limited number of genera that cannot easily be propagated by tissue cultures, as the Australian nursery industry had requested that the department review the existing policy and develop a new protocol based on updated information. Following the finalisation of the 2013 review, it was determined that dormant cuttings and budwood of a limited number of genera could be imported from countries where *P. ramorum* is known to occur, subject to strict import conditions.

Surveys conducted in response to *P. ramorum* outbreaks identified several new species of *Phytophthora* including *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae* (Martin & Tooley 2003; Schwingle et al. 2006; Webber 2008; Wickland et al. 2008; Fichtner et al. 2011). These *Phytophthora* species share a similar host range and geographic range with *P. ramorum* (Martin et al. 2004; Linzer & Garbelotto 2008; Webber 2008; Wickland et al. 2008). Additionally, symptoms caused by these *Phytophthora* species are indistinguishable from those caused by *P. ramorum* (Martin & Tooley 2003). Therefore, this review also considered the newly identified *Phytophthora* species, including *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae.*

1.2.2 Scope

The scope of this review is limited to:

- the revision of the existing policy to import *Phytophthora ramorum* host material;
- the revision of the host list for *P. kernoviae*, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum*; and
- the development of phytosanitary measures to import host material of *P. kernoviae*, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum*.

This review does not consider existing phytosanitary measures during the pest risk assessment. Existing phytosanitary measures are only considered during the development of risk management measures, if they are required, following the pest risk assessment.

This final review of policy is limited to recommending appropriate phytosanitary measures to address the risk of introducing *P. kernoviae*, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum* into Australia. It is the importer's responsibility to ensure compliance with the requirements of all other regulatory and advisory bodies associated with importing commodities to Australia. Among others, these could include the Department of Immigration and Border Protection, Department of Health, Therapeutic Goods Administration, Australian Pesticides and Veterinary Medicines Authority, Department of the Environment, and state and territory departments of agriculture.

2 Method for pest risk analysis

The department has conducted this pest risk analysis (PRA) in accordance with the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: *Framework for pest risk analysis* (FAO 2007) and ISPM 11: *Pest risk analysis for quarantine pests* (FAO 2013) that have been developed under the SPS Agreement (WTO 1995).

Phytosanitary terms used in this PRA are defined in ISPM 5: *Glossary of phytosanitary terms* (FAO 2015). A glossary of the terms used is provided at the back of this report.

The PRAs are conducted in the following three consecutive stages: initiation, pest risk assessment and pest risk management.

2.1 Stage 1: Initiation

The initiation of a pest risk analysis identifies pest(s) and pathway(s) that should be considered for risk analysis in relation to the identified PRA area. For this PRA, the 'PRA area' is defined as Australia for *Phytophthora* species (*P. kernoviae, P. nemorosa*, *P. pseudosyringae* and *P. ramorum*) that are absent from Australia.

This pest risk analysis was initiated as a basis for a review and possible revision of the current phytosanitary regulations to import hosts of *P. ramorum*. Since 2002, *P. ramorum* has been treated as a quarantine pest and is regulated on propagative material entering Australia. However, considerable research on *P. ramorum* has provided substantial new knowledge about the pathogen during the past decade. The PRA takes into account newly published information in the review of Australian emergency phytosanitary measures for *P. ramorum*.

Since the description of *Phytophthora ramorum* in 2001 (Werres et al. 2001; Rizzo et al. 2002b), several other aerially dispersed *Phytophthora* species, including *P. kernoviae, P. nemorosa* and *P. pseudosyringae*, with similar host ranges and geographic distributions to *P. ramorum* have been identified and are included in this PRA.

In the context of this assessment, *Phytophthora* species host propagative material (including tissue cultures, bare-rooted plants, dormant cuttings and budwood) is a potential import 'pathway' by which these *Phytophthora* species could enter Australia.

2.2 Stage 2: Pest risk assessment

A pest risk assessment (for quarantine pests) is the 'evaluation of the probability of the introduction and spread of a pest and the magnitude of the associated potential economic consequences' (FAO 2015). The pest risk assessment provides technical justification for identifying quarantine pests and for establishing phytosanitary import requirements.

The following three consecutive steps were used in the pest risk assessment:

- pest categorisation;
- assessment of the probability of entry, establishment and spread; and

- assessment of potential consequences.

2.2.1 Pest categorisation

Pest categorisation identifies which of the pests with the potential to be on the commodity are quarantine pests for Australia and require a pest risk assessment. A 'quarantine pest' is a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO 2015).

The process of a pest categorisation is summarised by ISPM 11 (FAO 2013) as a screening procedure based on the following criteria:

- identity of the pest;
- presence or absence in the PRA area;
- regulatory status;
- potential for establishment and spread in the PRA area; and
- potential for economic consequences (including environmental consequences) in the PRA area.

2.2.2 Assessment of the probability of entry, establishment and spread

Details of how to assess the 'probability of entry', 'probability of establishment' and 'probability of spread' of a pest are given in ISPM 11 (FAO 2013). A summary of this process is given below, followed by a description of the qualitative methodology used in this PRA.

Probability of entry

The probability of entry describes the probability that a quarantine pest will enter Australia as a result of trade in a given commodity, be distributed in a viable state in the PRA area and subsequently be transferred to a host. Assessing the probability of entry requires an analysis of each of the pathways with which a pest may be associated, from its origin to its distribution in the PRA area.

For the purpose of considering the probability of entry, the department divides this step into two components:

- **Probability of importation**: the probability that a pest will arrive in Australia when a given commodity is imported; and
- **Probability of distribution**: the probability that the pest will be distributed, as a result of the processing, sale or disposal of the commodity, in the PRA area and subsequently transfer to a susceptible host.

Factors considered in the probability of importation include the:

- distribution and incidence of the pest in the source area;
- occurrence of the pest in a life-stage that would be associated with the commodity;
- mode of trade (for example, bulk, packed);

- volume and frequency of movement of the commodity along each pathway;
- seasonal timing of imports;
- pest management, cultural and commercial procedures applied at the place of origin;
- speed of transport and conditions of storage compared with the duration of the lifecycle of the pest;
- vulnerability of the life-stages of the pest during transport or storage;
- incidence of the pest likely to be associated with a consignment; and
- commercial procedures (for example, refrigeration) applied to consignments during transport and storage in the country of origin, and during transport to Australia.

Factors considered in the probability of distribution include the:

- commercial procedures (for example, refrigeration) applied to consignments during distribution in Australia;
- dispersal mechanisms of the pest, including vectors, to allow movement from the pathway to a host;
- whether the imported commodity is to be sent to a few or many destination points in the PRA area;
- proximity of entry, transit and destination points to hosts;
- time of year at which importation takes place;
- intended use of the commodity (for planting, processing or consumption); and
- risks from by-products and waste.

Probability of establishment

Establishment is defined as the 'perpetuation for the foreseeable future, of a pest within an area after entry' (FAO 2015). In order to estimate the probability of establishment of a pest, reliable biological information (lifecycle, host range, epidemiology, and survival) is obtained from the areas where the pest currently occurs. The situation in the PRA area can then be compared with that in the areas where it currently occurs and expert judgement used to assess the probability of establishment.

Factors considered in the probability of establishment in the PRA area include the:

- availability of hosts, alternative hosts and vectors;
- suitability of the environment;
- reproductive strategy and potential for adaptation;
- minimum population needed for establishment; and
- cultural practices and control measures.

Probability of spread

Spread is defined as 'the expansion of the geographical distribution of a pest within an area' (FAO 2015). The probability of spread considers the factors relevant to the movement of the pest, after establishment on a host plant or plants, to other susceptible host plants of the same or different species in other areas. In order to estimate the probability of spread of the pest, reliable biological information is obtained from areas where the pest currently occurs. The situation in the PRA area is then carefully compared with that in the areas where the pest currently occurs and expert judgement is used to assess the probability of spread.

Factors considered in the probability of spread include the:

- suitability of the natural and/or managed environment for natural spread of the pest;
- presence of natural barriers;
- potential for movement with commodities, conveyances or by vectors;
- intended use of the commodity; and
- potential vectors of the pest in the PRA area.

Assigning qualitative likelihoods for entry, establishment and spread

In its qualitative PRAs, the department uses the term 'likelihood' for the descriptors it uses for its estimates of probability of entry, establishment and spread. Qualitative likelihoods are assigned to each step of entry, establishment and spread. Six descriptors are used: high, moderate, low, very low, extremely low and negligible (Table 1). Definitions for these descriptors and their indicative probability ranges are given in Table 1. The indicative probability ranges are only provided to illustrate the boundaries of the descriptors and are not used beyond this purpose in qualitative PRAs. These indicative probability ranges provide guidance to the risk analyst and promotes consistency between different pest risk assessments.

Table 1 Nomenclature of qualitative likelihoods

Likelihood	Descriptive definition	Indicative probability (P) range
High	The event would be very likely to occur	$0.7 < P \leq 1$
Moderate	The event would occur with an even probability	$0.3 < P \leq 0.7$
Low	The event would be unlikely to occur	$0.05 < P \leq 0.3$
Very low	The event would be very unlikely to occur	$0.001 < P \leq 0.05$
Extremely low	The event would be extremely unlikely to occur	$0.000001 < P \leq 0.001$
Negligible	The event would almost certainly not occur	$0 < P \leq 0.000001$

The likelihood of entry is determined by combining the likelihood that the pest will be imported into the PRA area and the likelihood that the pest will be distributed within the PRA area, using a matrix of rules (Table 2). This matrix is then used to combine the likelihood of entry and the likelihood of establishment, and then the likelihood of entry and establishment is combined with the likelihood of spread to determine the overall likelihood of entry, establishment and spread.

Table 2 Matrix of rules for combining qualitative likelihoods

	High	Moderate	Low	Very low	Extremely low	Negligible
High	High	Moderate	Low	Very low	Extremely low	Negligible
Moderate		Low	Low	Very low	Extremely low	Negligible
Low			Very low	Very low	Extremely low	Negligible
Very low				Extremely low	Extremely low	Negligible
Extremely low					Negligible	Negligible
Negligible						Negligible

For example, if the likelihood of importation is assigned a descriptor of 'low' and the likelihood of distribution is assigned a descriptor of 'moderate', then they are combined to give a likelihood of 'low' for entry. Then if the likelihood of establishment has been assigned a descriptor of 'high', this will be combined with the likelihood of entry (low), to give a likelihood for entry and establishment of 'low'. The assigned likelihood for spread (for example 'very low') would then be combined with the likelihood for entry and establishment (low), to give an overall likelihood for entry, establishment and spread of 'very low'. This can be summarised as:

importation x distribution = entry [E] **low x moderate = low**

entry [E] x establishment = [EE] **low x high = low**

[EE] x spread = [EES] **low x very low = very low**

Time and volume of trade

One factor affecting the likelihood of entry is the volume and duration of trade. If all other conditions remain the same, the overall likelihood of entry will increase as time passes and the overall volume of trade increases.

The department normally considers the likelihood of entry on the basis of the estimated volume of one year's trade. However, in the case of a high risk commodity the volume of trade is restricted to certain numbers. Therefore, other factors listed in ISPM 11 (FAO 2013) may not be relevant to propagative material of a high risk commodity.

2.2.3 Assessment of potential consequences

The objective of the consequence assessment is to provide a structured and transparent analysis of the likely consequences if the pest or disease agents were to enter, establish and spread in Australia. The assessment considers direct and indirect pest effects and their economic and environmental consequences. The requirements for assessing the potential consequences are given in Article 5.3 of the SPS Agreement (WTO 1995), ISPM 5 (FAO 2015) and ISPM 11 (FAO 2013).

Direct pest effects are considered in the context of the effects on:

- plant life or health; and
- other aspects of the environment.

Indirect pest effects are considered in the context of the effects on:

- eradication, control, etc;
- domestic trade;
- international trade; and
- the environment.

For each of these six criteria, the consequences were estimated over four geographic levels, defined as:

Local: an aggregate of households or enterprises (a rural community, a town or a local government area).

District: a geographically or geopolitically associated collection of aggregates (generally a recognised section of a state or territory, such as 'Far North Queensland').

Regional: a geographically or geopolitically associated collection of districts in a geographic area (generally a state or territory, although there may be exceptions with larger states such as Western Australia).

National: Australia wide (Australian mainland states, territories and Tasmania).

For each criterion, the magnitude of the potential consequences at each of these levels was described using four categories, defined as:

Indiscernible: pest impact unlikely to be noticeable.

Minor significance: expected to lead to a minor increase in mortality/morbidity of hosts or a minor decrease in production but not expected to threaten the economic viability of production. Expected to decrease the value of non-commercial criteria but not threaten the criterion's intrinsic value. Effects would generally be reversible.

Significant: expected to threaten the economic viability of production through a moderate increase in mortality/morbidity of hosts, or a moderate decrease in production. Expected to significantly diminish or threaten the intrinsic value of non-commercial criteria. Effects may not be reversible.

Major significance: expected to threaten the economic viability through a large increase in mortality/morbidity of hosts, or a large decrease in production. Expected to severely or irreversibly damage the intrinsic 'value' of non-commercial criteria.

The estimates of the magnitude of the potential consequences over the four geographic levels were translated into a qualitative impact score (A to G) using Table 3. For example, a consequence with a magnitude of 'significant' at the 'district' level will have a consequence impact score of D.

Table 3 Decision rules for determining the consequence impact score based on the magnitude of consequences at four geographic scales

	Geographic scale			
Magnitude	Local	District	Region	Nation
Indiscernible	A	A	A	A
Minor significance	B	C	D	E
Significant	C	D	E	F
Major significance	D	E	F	G

Note: In earlier qualitative PRA's, the scale for the impact scores went from A to F and did not explicitly allow for the rating 'indiscernible' at all four levels. This combination might be applicable for some criteria. In this report, the impact scale of A to F has been changed to become B–G and a new lowest category A ('indiscernible' at all four levels) was added. The rules for combining impacts in Table 4 were adjusted accordingly. The decision rules for determining the consequence impact score are presented in a simpler form in Table 3 from earlier PRAs, to make the table easier to use. The outcome of the decision rules is the same as the previous table and makes no difference to the final impact score.

The overall consequence for each pest is achieved by combining the qualitative impact scores (A–G) for each direct and indirect consequence using a series of decision rules (Table 4). These rules are mutually exclusive, and are assessed in numerical order until one applies.

Table 4 Decision rules for determining the overall consequence rating for each pest

Rule	The impact scores for consequences of direct and indirect criteria	Overall consequence rating
1	Any criterion has an impact of 'G'; or more than one criterion has an impact of 'F'; or a single criterion has an impact of 'F' and each remaining criterion an 'E'.	Extreme
2	A single criterion has an impact of 'F'; or all criteria have an impact of 'E'.	High
3	One or more criteria have an impact of 'E'; or all criteria have an impact of 'D'.	Moderate
4	One or more criteria have an impact of 'D'; or all criteria have an impact of 'C'.	Low
5	One or more criteria have an impact of 'C'; or all criteria have an impact of 'B'.	Very Low
6	One or more but not all criteria have an impact of 'B'; and all remaining criteria have an impact of 'A'.	Negligible

2.2.4 Estimation of the unrestricted risk

Once the above assessments are completed, the unrestricted risk can be determined for each pest or groups of pests. This is determined by using a risk estimation matrix (Table 5) to combine the estimates of the probability of entry, establishment and spread and the overall consequences of pest establishment and spread. Therefore, risk is the product of likelihood and consequence.

When interpreting the risk estimation matrix, note the descriptors for each axis are similar (for example, low, moderate, high) but the vertical axis refers to likelihood and the horizontal axis refers to consequences. Accordingly, a 'low' likelihood combined with 'high' consequences, is not the same as a 'high' likelihood combined with 'low' consequences—the matrix is not symmetrical. For example, the former combination would give an unrestricted risk rating of 'moderate', whereas the latter would be rated as a 'low' unrestricted risk.

Table 5 Risk estimation matrix

Likelihood of pest entry, establishment and spread	Consequences of pest entry, establishment and spread					
	Negligible	Very low	Low	Moderate	High	Extreme
High	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Moderate	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Low	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk	High risk
Very low	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk
Extremely low	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk
Negligible	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk

2.2.5 Australia's appropriate level of protection (ALOP)

The Sanitary and Phytosanitary (SPS) Agreement defines the concept of an 'appropriate level of sanitary or phytosanitary protection (ALOP)' as the level of protection deemed appropriate by a World Trade Organisation (WTO) member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory.

Like many other countries, Australia expresses its ALOP in qualitative terms. Australia's ALOP, which reflects community expectations through government policy, is currently expressed as providing a high level of sanitary or phytosanitary protection aimed at reducing risk to a very low level, but not to zero. The band of cells in Table 5 marked 'very low risk' represents Australia's ALOP.

2.3 Stage 3: Pest risk management

Pest risk management evaluates and selects risk management options to reduce the risk of entry, establishment or spread of identified pests for the identified import pathways. To effectively prevent the introduction of pests associated with an identified pathway, a series of important safeguards, conditions or phytosanitary measures must be in place. Propagative material represents a direct pathway for pests identified by the pest categorisation. This pathway is direct since the end-use is the planting of a known host plant.

2.3.1 Identification and selection of appropriate risk management options

Phytosanitary measures to prevent the establishment and spread of quarantine pests may include any combination of measures, including pre- or post-harvest treatments, inspection at various points between production and final distribution, surveillance, official control, documentation or certification. A measure or combination of measures may be applied at any one or more points along the continuum between the point of origin and the final destination. Pest risk management explores options that can be implemented (i) in the exporting country, (ii) at the point of entry or (iii) within the importing country. The ultimate goal is to protect plants and prevent the introduction of identified quarantine pests.

Examples of phytosanitary measures which may be applied to propagative material consignments include:

- **Import from pest free areas only** (**ISPM 4, 10**)—the establishment and use of a pest free area by a National Plant Protection Organisation (NPPO) provides for the export of plants from the exporting country to the importing country without the need for application of additional phytosanitary measures when certain requirements are met.
- **Inspections or testing for freedom from regulated pests**—this is a practical measure for visible pests or for pests which produce visible symptoms on plants.
- **Inspection and certification** (**ISPM 7, 12, 23**)—the exporting country may be asked to inspect the shipment and certify that the shipment is free from regulated pests before export.
- **Specified conditions for preparation of the consignment**—the importing country may specify steps that must be followed in order to prepare the consignment for shipment. These conditions can include the requirement for plants to be produced from appropriately tested parent material.
- **Pre-entry or post-entry quarantine**—the importing country may define certain control conditions, inspection and possible treatment of shipments upon their entry into the country. Post-entry quarantine (PEQ) of dormant cuttings, seed and even tissue cultures (*in vitro* plantlets) can help avoid the introduction of new viruses or allied pathogens into the importing countries.
- **Removal of the pest from the consignment by treatment or other methods**—the importing country may specify chemical or physical treatments that must be applied to the consignment before it may be imported.

Measures can range from total prohibition to permitting imports subject to visual inspection. In some cases, more than one phytosanitary measure may be required in order to reduce the pest risk to an acceptable level.

3 The pathogens

The genus *Phytophthora* comprises over 117 described species worldwide (Martin et al. 2012), with some species being well known pathogens of agriculture, nursery and forestry industries (Weste & Marks 1987; Erwin & Ribeiro 1996; Birch & Whisson 2001; Orlikowski et al. 2010). Since 1990, there has been a dramatic increase in the number of *Phytophthora* species isolated, identified and described (Werres et al. 2001; Hansen et al. 2003a; Jung et al. 2003; Brasier et al. 2005; Donahoo et al. 2006; Durán et al. 2008; Mostowfizadeh-Ghalamfarsa et al. 2008). Surveys conducted in response to *P. ramorum* have identified several new species of *Phytophthora* on ornamental plants and in forests in Europe and the United States of America (USA) (Theman et al. 2002; Hansen et al. 2003a; Jung et al. 2003; Blomquist et al. 2005; Donahoo et al. 2006; Schwingle et al. 2006; 2007; Hong et al. 2008; Schwingle & Blanchette 2008; Moralejo et al. 2008; Yakabe et al. 2009; Grünwald et al. 2011).

In 2001, *Phytophthora ramorum* was first described as a new *Phytophthora* species on *Rhododendron* and *Viburnum* species in Germany and the Netherlands (Werres et al. 2001). *Phytophthora kernoviae* was first recorded in New Zealand in the 1950s but was described only in 2005 (Brasier et al. 2005) and was previously known as *Phytophthora* taxon C (Hughes et al. 2005). Two *Phytophthora* species that have an aerial habit were frequently isolated from the foliage and stems of some of the same hosts as *P. ramorum* in California and Oregon, USA (Rizzo et al. 2002a; Hansen et al. 2003a; Martin & Tooley 2003). These *Phytophthora* species were initially referred to as *P. ilicis*-like due to morphological and DNA sequence similarities with the leaf and twig blight pathogen of English holly (Rizzo et al. 2002a). However, later on it was determined that the *P. ilicis*-like species comprised of two separate taxa; one species was subsequently described as *P. nemorosa* (Hansen et al. 2003a) and the other was identified as *P. pseudosyringae* (Martin & Tooley 2003; Ivors et al. 2004; Martin et al. 2004). *Phytophthora nemorosa* is known only from California and Oregon (Hansen et al. 2003a), while *P. pseudosyringae* was originally isolated from soil in European oak and beech forests (Jung et al. 2003). *Phytophthora pseudosyringae* was described in 2003 based on European isolates which had been collected since 1996 from forest soil collected in France, Germany and Italy, and from roots of European beech and European alder (Jung et al. 2003).

Phytophthora kernoviae has been detected as a shrub and tree pathogen, and has now been detected in ornamental nurseries in the United Kingdom (UK) (Brasier et al. 2005). *Phytophthora pseudosyringae* was reported from Italy causing stem canker on European beech and stem damage on chestnut in Spain (Sansford 2012). *Phytophthora pseudosyringae* has also been reported from the USA affecting various tree and non-tree species in California and Oregon, and from forest streams in North Carolina. *Phytophthora nemorosa* and *P. pseudosyringae* were initially detected as forest pathogens (Hansen et al. 2003a; Jung et al. 2003) but have now also been detected on ornamentals (Yakabe et al. 2009; Grünwald et al. 2011).

Phytophthora nemorosa and *P. pseudosyringae* have similar host ranges and occur in generally the same geographic region as *P. ramorum* (Martin & Tooley 2003; Martin et al. 2004; Wickland et al. 2008). *Phytophthora nemorosa* is commonly isolated from leaf spots (Yakabe et al. 2009) and twig cankers but occasionally has been observed causing lethal cankers (Hansen et al. 2003a). *Phytophthora pseudosyringae* is associated with declining oaks, beeches and alders in Europe, where it has been described as a root and stem pathogen (Jung et al. 2003; Diana et al.

2006; Hwang et al. 2007). *Phytophthora pseudosyringae* has also been observed as a leaf and twig pathogen (Martin & Tooley 2003) and has been reported causing disease on chestnut nursery stock in Spain (Varela et al. 2007).

Some plants are a host to multiple *Phytophthora* species, thus increasing the probability of the inadvertent introduction of exotic pathogens. Among these newly described *Phytophthora* species, *P. kernoviae*, *P. nemorosa*, and *P. pseudosyringae* have multiple overlapping hosts and are established in temperate forest ecosystems and ornamental nurseries (Webber 2008; Yakabe et al. 2009; Grünwald et al. 2011). These *Phytophthora* species produce symptoms indistinguishable from *P. ramorum* on shared hosts and have a significant aerial component in their life cycle (Davidson et al. 2005; 2008; Martin et al. 2012).

3.1 Symptoms produced by the *Phytophthora* species

Symptoms caused by *Phytophthora kernoviae*, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum* include leaf necrosis, shoot tip dieback and bleeding cankers on a wide range of plant species (Denman et al. 2005; Linzer & Garbelotto 2008; Linzer et al. 2009). Symptoms caused by these species are indistinguishable on shared hosts; therefore, the biological information of *P. ramorum* will be used for the purposes of this review.

Phytophthora ramorum produces symptoms that include bleeding lesions, stem cankers, twig dieback and/or foliar lesions (Hansen et al. 2005; Rizzo et al. 2005). Lethal trunk cankers are produced on members of the Fagaceae family; for example, oaks, tanoak and European beech (Parke & Lucas 2008; Parke & Rizzo 2011; Dick & Parke 2012). Non-lethal shoot die-back symptoms are produced on some Ericaceae and conifers, and foliar blight on a diverse group of hosts (Parke & Rizzo 2011; Dick & Parke 2012). Foliar infections are not fatal but these foliar hosts play an important role in spreading the inoculum of the pathogen (Alexander 2012). In addition, *P. kernoviae* also produces symptoms on the fruits of custard apples (*Annona cherimola*), with infected fruits becoming mummified (Ramsfield et al. 2009).

3.2 Biology of the *Phytophthora* species

Phytophthora species are oomycetes (water moulds) and require a moist environment (abundant water in soil or on foliage) to actively grow and reproduce (Erwin & Ribeiro 1996). Reproduction in *Phytophthora* species is either sexual or asexual, although some species have not been observed in the sexual phase.

During the asexual life cycle, these pathogens can be observed in different life stages including mycelia, sporangia, zoospores, cysts and germinating cysts (Savidor et al. 2008). Asexual reproduction occurs through the production of sporangia, which can germinate directly or release motile zoospores. These zoospores are water-borne and move with the aid of two flagella (Dick 2001). Subsequently, a zoospore encysts, losing its flagella, and attaches to its host and germinates (Nogueira et al. 1977; Blanco & Judelson 2005). Zoospores are spread in water through rain-splash, wind-blown rain or run-off into water ways. Wind-dispersal of *P. ramorum* sporangia has also been reported in the forests of the Pacific Northwest USA (Davidson et al. 2002a; Denman et al. 2006). Some *Phytophthora* species can also produce asexual chlamydospores that are able to survive unfavourable conditions for longer periods than sporangia or zoospores (Erwin & Ribeiro 1996). Soil contaminated with sporangia, oospores or chlamydospores is another mode of dispersal in the forest which can be spread on muddy vehicle tyres or boots (Hansen et al. 2000).

Sexual reproduction can be homothallic or heterothallic, requiring the interaction of opposite mating types for sexual recombination (Erwin & Ribeiro 1996; Ivors et al. 2004). During the sexual life cycle, oospores (sexual spores) that can survive in the soil for years are produced, thus allowing re-infection of their host plant in subsequent growing seasons (Savidor et al. 2008). However, because the oospores require a dormancy period of several weeks before germination, it is the asexual life cycle (sporangia, zoospores, chlamydospores) that is responsible for the rapid propagation and spread of *P. ramorum* (Savidor et al. 2008).

The morphological characteristics of *P. kernoviae*, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum* are presented in Table 6.

Table 6 Characteristics of the *Phytophthora* species under review

	***Phytophthora* species**			
	P. kernoviae	***P. nemorosa***	***P. pseudosyringae***	***P. ramorum***
Common name	Kernoviae bleeding, canker/leaf blight	Leaf blight, twig canker	Leaf blight, twig canker	Sudden oak death, ramorum dieback/ leaf blight
Geographic distribution	Ireland, New Zealand, UK	USA	USA, Europe	Canada, Europe, USA
Hosts	Multiple	Multiple	Multiple	Multiple
Infected tissues	Stem/foliage	Stem/foliage	Foliage	Stem/foliage
Caducous sporangia	Yes	Yes	Yes	Yes
Reproduction	Homothallic	Homothallic	Homothallic	Heterothallic
Chlamydospores	No	No	No	Yes
Morphological group	I	III	III	IV
Phylogenetic clade	10	3	3	8c

Source: Waterhouse (1963); Blair et al. (2008); Chimento et al. (2012); Martin et al. (2012).

Phytophthora ramorum is known to produce large numbers of chlamydospores and caducous sporangia (Martin et al. 2012). *Phytophthora ramorum* is heterothallic and requires two different mating types known as A1 and A2 to reproduce sexually. The A1 mating type is found predominantly in Europe and the A2 predominantly in the USA (Ivors et al. 2004). *Phytophthora ramorum* is adapted to cool temperatures with optimal growth at 20 °C. Molecular phylogeny shows that *P. ramorum* is most closely related to *P. lateralis* and *P. hibernalis* (Parke & Lucas 2008). Currently, three clonal lineages of *P. ramorum* are recognized and have been named after the continent (NA = North America; EU = Europe) on which they were first found: EU1, NA1 and NA2 (Grünwald et al. 2009). EU1 only affects Europe, while all three lineages are found in the USA (Goss et al. 2009a, b; 2011). It has also become evident that the EU1 clonal lineage was moved from Europe to North America most likely via the movement of ornamental plants such as *Rhododendron* species (Goss et al. 2011). Despite the occasional presence of both mating types in nursery environments of western USA, sexual reproduction has to date not been found (Kliejunas 2010; Goss et al. 2011; Grünwald et al. 2012).

Phytophthora kernoviae is known to be homothallic, lacking chlamydospores (Widmer 2011) and produces large numbers of oospores and caducous sporangia (Brasier et al. 2005). The optimal temperature range for the growth of *P. kernoviae* is between 18 °C and 26 °C (Brasier et al. 2005), which indicates that *P. kernoviae* may be adapted to a temperate climate. Oospores of *P. kernoviae* can survive for long periods at temperatures of 30 °C and below; however, viability is reduced by exposure to higher temperatures (Widmer 2011). *Phytophthora kernoviae* is closely related to *P. boehmeriae* (Brasier et al. 2005). Morphologically, *P. kernoviae* (homothallic and lacking chlamydospores) is readily distinguished from *P. ramorum* (Werres et al. 2001). Phylogenetically, *P. kernoviae* falls in ITS DNA Clade 10 (Cooke et al. 2000; Blair et al. 2008) with *P. boehmeriae, P. gallica* and *P. morindae*.

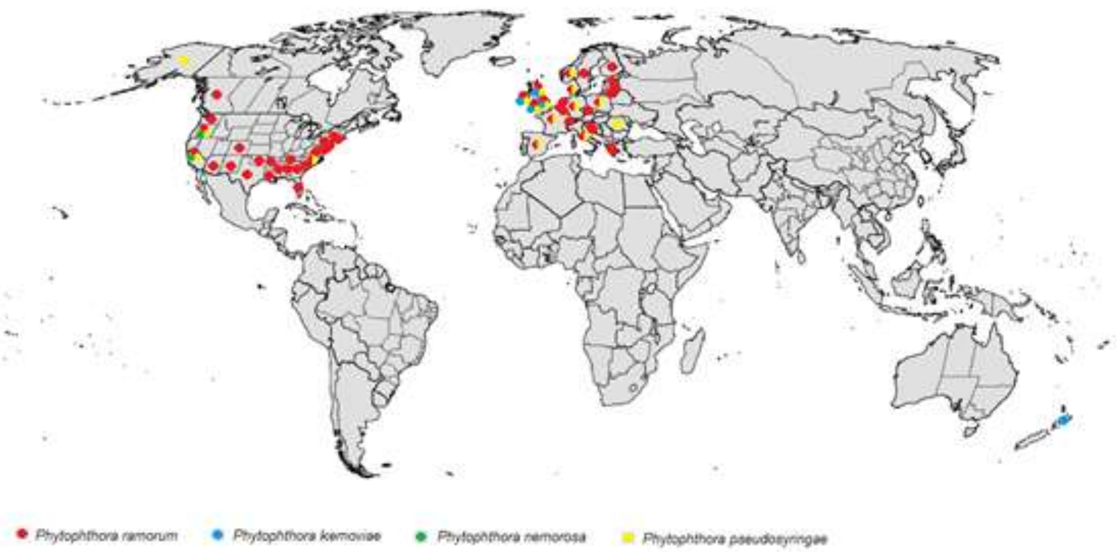
Phytophthora nemorosa and *P. pseudosyringae* are both homothallic (Linzer et al. 2009), have similar host ranges and occur in generally the same geographic region as *P. ramorum* in Californian forests. *Phytophthora nemorosa* and *P. ramorum* are similar in host range and symptomology (Hansen et al. 2003a); however in culture, *P. nemorosa* grows more slowly, with a lower temperature optimum (15 °C) than *P. ramorum* (20 °C) (Hansen et al. 2003a). Morphologically, *P. nemorosa* is homothallic and lacking chlamydospores, so it is readily distinguished from *P. ramorum* (Werres et al. 2001). Phylogenetically, *P. nemorosa* falls in ITS DNA Clade 3 (Cooke et al. 2000) with *P. ilicis, P. psychrophila, P. pseudosyringae* (Jung et al. 2003) and *P. quercine* (Jung et al. 1999).

3.3 Global occurrence of the *Phytophthora* species

Phytophthora ramorum was first reported to be associated with twig blight disease on *Rhododendron* and *Viburnum* species in Germany and the Netherlands (Werres et al. 2001) and on *Quercus* and *Lithocarpus* species in California, USA (Rizzo et al. 2002b). Since then, it has been reported from Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, the UK and the USA (Goheen & Frankel 2009) (Map 3).

Phytophthora ramorum is speculated to have originated from East Asia; however, a closely related species, *Phytophthora lateralis*, has been found on *Chamaecyparis* species in Taiwan (Brasier et al. 2010). *Phytophthora lateralis* and *P. ramorum* are phylogenetically related; they have various common features and are thus likely to share a common region of origin (Brasier et al. 2010). *Chamaecyparis* species (conifers) are present both in Taiwan and Japan; therefore, both *Phytophthora* species could have originated from one of these two countries (Brasier et al. 2010). The known distribution of *P. ramorum* includes nurseries of ornamental plants in Europe and North America as well as in wild woodlands of western USA (Werres et al. 2001; Rizzo et al. 2002b; Davidson et al. 2003b) and forests in Europe (Brasier et al. 2004a; Brasier & Webber 2010). *Phytophthora ramorum* is regarded as an exotic pathogen of unknown origin to both Europe and the USA (Rizzo & Garbelotto 2003; Ivors et al. 2004; 2006). *Phytophthora nemorosa* and *P. pseudosyringae* are also considered exotic and have been introduced into California and Oregon, USA (Linzer et al. 2006).

Map 3 Global occurrences of *Phytophthora* species



Phytophthora kernoviae was speculated to have been introduced into the UK from Asia or South America (Ramsfield et al. 2007); however, historical data indicates that it was first recorded in New Zealand as a *Phytophthora* species in the 1950s (Brasier et al. 2005). Molecular studies of *Phytophthora* species in New Zealand culture collections revealed an isolate of *P. kernoviae* recovered in 2002 from custard apple (*Annona cherimola*) orchards*. Phytophthora kernoviae* was causing leaf, shoot and fruit disease of *Annona cherimola* in the North Island, New Zealand (Ramsfield et al. 2009). Further studies have shown that *P. kernoviae* is present in soils in both indigenous and exotic forests in several regions of the North Island, New Zealand (Ramsfield et al. 2009).

Phytophthora nemorosa and *P. pseudosyringae* have similar host and geographic ranges and cause similar disease symptoms to *P. ramorum* (Hansen et al. 2003a; Murphy & Rizzo 2006; Wickland & Rizzo 2006). However, *P. nemorosa* and *P. pseudosyringae* do not appear to cause mortality of oaks or tanoak and infect fewer plant species than *P. ramorum* (Murphy et al. 2008). While all three pathogens are patchy over the landscape, *P. nemorosa* and *P. pseudosyringae* are distributed over a broader geographical area than *P. ramorum,* extending into the Sierra Nevada, USA (Murphy et al. 2008).

3.4 Hosts of the *Phytophthora* species

Known hosts of the *Phytophthora* species (*P. kernoviae*, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum*) include numerous species in a wide range of plant families (Appendix A). However, it should be noted that an increasing number of new hosts of these pathogens are being identified; therefore, the department will continue to review the host list as necessary. Details of the important hosts of *P. ramorum*—with mention of *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae*—are provided below.

- **Caprifoliaceae** includes nursery and landscape species worldwide, particularly the genus *Viburnum*—one of the first plants *P. ramorum* was isolated from was *Viburnum bodnantense* in Europe (Werres et al. 2001). This genus has been implicated in the introduction of *P. ramorum* into new areas (Sansford et al. 2009).

- **Ericaceae** includes groups of nursery, landscape, environmental and small fruit production plants (*Calluna vulgaris*, *Kalmia* species, *Pieris* species, *Rhododendron* species and *Vaccinium* species). One of the first plants *P. ramorum* was isolated from was *Rhododendron* species in Europe (Werres et al. 2001). *Rhododendron* species are a host of several *Phytophthora* species and have been implicated in the introduction of *P. ramorum* into new areas. *Rhododendron* species play an important role in *P. ramorum* epidemics as the pathogen sporulates profusely on this host (Sansford et al. 2009). *Rhododendron* species are asymptomatic hosts of *P. ramorum* and *P. kernoviae* (Brasier 2007). *Rhododendron* species are a host of several *Phytophthora* species that can attack woody hosts; therefore, *Rhododendron* may be the ideal universal '*Phytophthora* carrier' (Brasier 2007). *Phytophthora pseudosyringae* was first reported on *Vaccinium myrtillus* (Beales et al. 2009).
- **Fagaceae** includes forest species (oaks) where *P. ramorum* was first reported from California causing Sudden oak death (Sansford et al. 2009). Oak infection is a comparatively rare event and usually occurs with the association of infected bay laurel (Kelly & Meentemeyer 2002; Swiecki & Bernhardt 2002a, b; Davidson et al. 2005). The infection process is followed by a much slower process of host colonisation, lasting between six months to several years (Rizzo & Garbelotto 2003).
- **Lauraceae** includes *Umbellularia californica* (bay laurel), a sporulating host that can act as an important source of inoculum of *P. ramorum*. The presence of *U. californica* plays an important role in sudden oak death incidence in *Quercus* and *Lithocarpus* species in California (Kelly & Meentemeyer 2002; Swiecki & Bernhardt 2002a, b; Meshriy et al. 2006).
- **Magnoliaceae** includes ornamental and forest plants; for example, *Manglietia insignis, Magnolia* species, *Michelia* species and *Parakmeria lotungensis.* These are all primarily foliar hosts of *P. ramorum* and *P. kernoviae*. It has been suggested that *P. kernoviae* might be more of a 'magnolia specialist' in its natural habitat (Brasier et al. 2005), although its host range in the UK extends beyond the Magnoliaceae.
- **Myrtaceae** includes forest and timber species (*Eucalyptus* species).
- **Oleaceae** includes horticultural plants (*Fraxinus latifolia*, *Osmanthus* species and *Syringa vulgaris*), which are foliar and shoot dieback *Phytophthora* hosts.
- **Pinaceae** includes timber species (*Abies* species, *Larix kaempferi, Pinus radiata* and *Pseudotsuga menziesii*).
- **Taxodiaceae** includes timber species (*Sequoia sempervirens*).
- **Theaceae** includes nursery and landscape plants (*Camellia* species). *Phytophthora ramorum* infected *Camellia* plants have been implicated in the introduction of the pathogen into new areas.
- **Winteraceae** includes ornamental species (*Drimys* species), which are foliar hosts of *P. kernoviae*.

Hosts of *P. ramorum* include lethal hosts (coast live oak, Californian black oak, shreve oak, canyon live oak and tanoak), non-lethal hosts (bay laurel, bigleaf maple, douglas-fir, honeysuckle, huckleberry and maidenhair ferns) and ornamentals (*Rhododendron* species, *Camellia* species, *Viburnum* species, *Pieris* species and wood rose). The host range for

P. kernoviae is less well known than for *P. ramorum*; however, *P. kernoviae* is more aggressive on beech tree stems (*Fagus sylvatica*) and the foliage of tulip trees (*Liriodendron tulipifera*) (Brasier et al. 2006). In addition, *P. kernoviae* is considered more pathogenic to *Rhododendron* species than *P. ramorum* and is capable of causing serious damage to *Fagus sylvatica* (NAPPO 2006). Therefore, *P. kernoviae* may be more of a specific threat to some species than *P. ramorum* (Widmer 2010).

3.5 Spread of the *Phytophthora* species

Phytophthora species are capable of natural spread in the ecosystem and through human activities. *Phytophthora ramorum* has been found in water, which can lead to plant infection (Tjosvold et al. 2009). This fungus spreads locally through rain-splash of sporangia formed on the foliage of certain hosts; for example, *Larix kaempferi*, *Rhododendron ponticum*, *Umbellularia californica*, or on twigs of *Lithocarpus densiflorus*. Long distance aerial dispersal of sporangia may occur during storms (Hansen et al. 2008); however, sporangia generally do not survive long distance transport due to desiccation (Ristaino & Gumpertz 2000) and it is unlikely that *Phytophthora* species will spread to other areas through this mechanism. Therefore, long distance spread will most likely be through human mediated transport of live plant material and/or infested soil (Widmer 2010). *Phytophthora kernoviae* is not known to produce chlamydospores; therefore, the propagules most likely involved in soil infestation will be oospores (Widmer 2010).

3.5.1 Spread in natural ecosystems

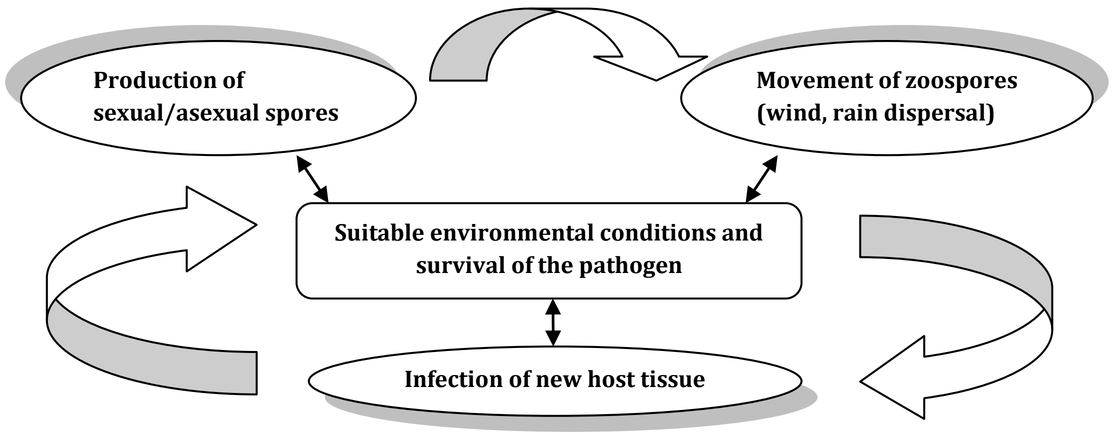
Phytophthora kernoviae, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum* have a significant aerial component of their life cycle (Davidson et al. 2005; 2008; Martin et al. 2012). These species spread through a cycle consisting of the production of asexual spores (sporangia and zoospores), movement of these spores and infection of new hosts. The new infection can then serve as another source of spores to begin the cycle again (Erwin & Ribeiro 1996; Werres et al. 2001; Davidson et al. 2005). Appropriate environmental conditions (temperature and relative humidity), as well as survival of the pathogen (either as spores or mycelia on a foliar host or in the soil), are necessary for each step of the cycle.

The first step in the life cycle of aerially dispersed *Phytophthora* species is the production of infective spores on or within living plant tissue (foliage, green stems and woody stems). Foliar hosts (bay laurel, Japanese larch and *Rhododendron* species) are an important source of inoculum for initiating plant infection. *Phytophthora* species produce deciduous sporangia (involved in pathogen dispersal) and chlamydospores on some foliar hosts (involved in survival during adverse conditions) (Figure 1).

In addition, chlamydospores are produced asexually in infected leaves, shoots, bark, phloem and xylem tissues (Parke et al. 2008), and have a major role in fungus survival through summer in a dormant or relatively inactive state (Werres et al. 2001; Davidson et al. 2005). The second step in the life cycle is the dispersal of pathogen propagules. Sporangia and zoospores are dispersed under wet conditions when temperatures are suitable. The final step in the reproductive cycle involves successful infection of new host tissue and reaching a susceptible host is essential. Studies indicate that the optimal infection of bay laurel leaves by zoospores of *P. ramorum* occurs at 20 °C.

Phytophthora ramorum requires a susceptible foliar host that supports high levels of sporulation (for example, *Arbutus unedo*, *Quercus ilex*, *Rhamnus alaternus*, *Rhododendron ponticum*, *Vaccinium* species and *Viburnum tinus*). Sporulation occurs on infected shoots and foliage but not on bleeding stem cankers; therefore, foliar hosts play an important role in disease epidemiology (Denman et al. 2008). Under wet and somewhat warm conditions, up to 17 000 spores per lesion are produced on infected leaves (Davidson et al. 2008). Susceptible foliar hosts and suitable climatic conditions therefore play a key role in the spread of *P. ramorum* into natural and semi-natural environments (Denman et al. 2006; Webber 2008).

Figure 1 The infection process of *Phytophthora* species



Phytophthora ramorum and *P. kernoviae* have been isolated from asymptomatic roots of naturally infected *Rhododendron ponticum*, suggesting that these pathogens have the ability to infect and colonize roots (Fichtner et al. 2011). This was the first report of root infections by *P. ramorum* and *P. kernoviae* on *R. ponticum*, and the first report of root infections of *P. kernoviae* on a host (Fichtner et al. 2011). Oospores produced in *R. ponticum* roots and foliage may serve as survival structures in soil. Additionally, roots may support polycyclic sporulation, thus producing sporangia near the soil surface which can then be splash dispersed to aboveground plant parts or serve as primary inoculum for new root infections.

Rivers and streams

Phytophthora species may disperse over long distances in rivers and streams with propagules having been detected from one to 20 kilometres downstream from probable inoculum sources (Davidson et al. 2005; Sutton et al. 2009; Reeser et al. 2011).

Rain and wind

Rain and wind play an important role in the dispersal of aerial *Phytophthora* species propagules in the ecosystem. Rain-splash and wind driven rain are important factors in the rapid spread of *Phytophthora* species within forests. Short distance rain-splash dispersal (10 to 15 meters) of *P. ramorum* has been reported in evergreen forests in California (Davidson et al. 2005). In Oregon, rain-splash and long distance *P. ramorum* dispersal (zero to four kilometres) in turbulent air currents has been reported (Hansen et al. 2008; Mascheretti et al. 2008).

3.5.2 Spread through human activity

Spread of these *Phytophthora* species via human-mediated means will be rapid and is significant through the commercial movement of infected plants for planting (Ivors et al. 2006; Grünwald et al. 2008a; Prospero et al. 2009). Spread through other human-mediated means includes soil/debris attached to footwear and on the tyres of bikes and cars (Brasier et al. 2007).

Nursery stock

The nursery trade is the main pathway for the worldwide introduction and spread of exotic pathogens including *P. ramorum* (Ivors et al. 2006; Grünwald et al. 2008a; Prospero et al. 2009). The introduction of *P. ramorum* into California is linked to the nursery trade (Ivors et al. 2006; Mascheretti et al. 2008). The rapid spread of *P. ramorum* within Europe and the USA through the trade of infected host plants is confirmed by the expansion of the geographical distribution of the pathogen.

- Plant trade has introduced *P. ramorum* and new genotypes of this pathogen into North America and Europe (Goss et al. 2011). The increased trade of plants between and within countries has provided new opportunities for plant pathogens to be moved to new areas or countries (Dehnen-Schmutz et al. 2010; Webber 2010; Wingfield et al. 2010; Stenlid et al. 2011). In Europe, *P. ramorum* has spread to many countries, primarily on nursery plants of *Rhododendron* and *Viburnum* species and recently on *Camellia japonica, Kalmia latifolia, Leucothoe* species, *Pieris formosa* var. *forrestii, Pieris japonica, Syringa vulgaris, Taxus baccata* and *Viburnum bodnantense* (Werres & De Merlier 2003; Husson et al. 2007).
- *Phytophthora ramorum* was introduced from one infected *Camellia* nursery to several states in the USA (Cave et al. 2008), indicating that the movement of nursery plants is the main pathway for the introduction of this pathogen into new areas (Alexander 2012).
- *Phytophthora ramorum* has been introduced with *Rhododendron* species shipments from Germany and the Netherlands into Norway (Sundheim et al. 2009); and from Belgium into Greece (Tsopelas et al. 2011). *Phytophthora ramorum* was detected on plant material from the USA in 2003 and from Canada in 2004 (Frankel 2008; Wong 2008).

Recreation and tourism

Spores of *P. ramorum* and *P. kernoviae* have been detected in soil adhering to the shoes of hikers and on the tyres of mountain bikes and vehicles leaving infested woodlands in California (Brasier et al. 2005; 2007; Shishkoff 2007) and the UK (Webber & Rose 2007). *Phytophthora ramorum* can survive eight to 11 months in the soil (Shishkoff 2007) and tourists carrying soil on their footwear may spread these pathogens internationally. *Phytophthora ramorum* can also be spread by animal vectors; snails, shore fly larvae and fungus gnat larvae are known carriers of fungal propagules including chlamydospores and sporangia (Hyder et al. 2009).

Soil/growing media

Phytophthora ramorum can survive for significant periods of time in soil (eight to 11 months) and growing media (> 12 months) (Linderman & Davis 2006a; Shishkoff 2007). Soil and growing media represent potential direct pathways if imported from areas where the pathogen occurs and if it is used for the planting of host plants (Parke & Lewis 2007).

4 Pest risk assessment for *Phytophthora* species

Phytophthora nemorosa and *P. pseudosyringae* are newly described species, detected during an intensive survey on *P. ramorum* in California and Oregon, USA (Hansen et al. 2003a). A similar survey in the UK found *P. kernoviae*, which was isolated most frequently from *Fagus sylvatica* and also from necrotic lesions of *Quercus robur* and *Liriodendron tulipifera* (Brasier et al. 2005). These newly identified *Phytophthora* species are similar to *P. ramorum* in several biological aspects, including the production of deciduous sporangia adapted for aerial dispersal, similar host ranges and occurrence in similar geographic regions (Webber 2008; Yakabe et al. 2009; Grünwald et al. 2011); therefore, this PRA covers all of these pathogens.

Phytophthora species are considered the most destructive pathogens of oak and non-oak plants as they cause a variety of direct and indirect economic impacts, such as reduced yield, reduced commodity value and the loss of foreign or domestic markets (Rizzo et al. 2002b; Dart & Chastagner 2007; Grünwald et al. 2008c). The assessed *Phytophthora* species (*P. ramorum, P. kernoviae*, *P. nemorosa* and *P. pseudosyringae*) are not present in Australia and fulfil the International Plant Protection Convention (IPPC) criteria for a quarantine pest. In this PRA, propagative material (tissue cultures, dormant cuttings, budwood and bare-rooted plants) are assessed as potential pathways for the importation of *Phytophthora* species into Australia; however, the risk assessment of these pathways are conducted together as the risk is deemed to be equivalent.

4.1 *Phytophthora ramorum, P. kernoviae, P. nemorosa* and *P. pseudosyringae*

Phytophthora kernoviae, *P. nemorosa* and *P. pseudosyringae* share several biological attributes (biology, host range and symptoms) with *P. ramorum*. Therefore, the knowledge of ecology and biology of *P. ramorum* can reasonably be extended to the other species within this group. Consequently, for the purposes of this risk assessment, the biological information of *Phytophthora ramorum* will be used to apply for all four species.

4.1.1 Likelihood of entry

The likelihood of entry is divided for assessment purposes into the likelihood of importation (the likelihood that the *Phytophthora* species will arrive when host propagative material is imported) and likelihood of distribution (the likelihood that the *Phytophthora* species arrived on host propagative material and will be transferred to another suitable site on a susceptible host).

Likelihood of importation

The likelihood that the *Phytophthora* species will arrive in Australia with trade in host plant propagative material from countries where the pathogen is present is **HIGH**.

Association of the pest with the pathway

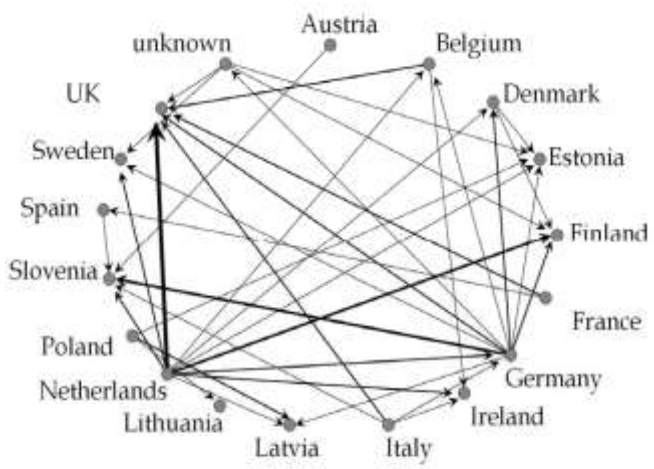
- *Phytophthora ramorum* has been reported in association with a wide range of host plants (Webber 2008; Yakabe et al. 2009; Grünwald et al. 2011) and has been introduced into several countries with trade in nursery stock. *Phytophthora ramorum* has been introduced from an unknown country into the USA and Europe, and *P. kernoviae* into the UK (Brasier et al. 2004a; Fichtner et al. 2012). *Phytophthora kernoviae*, *P. nemorosa* and *P. pseudosyringae* have a similar host range, and occur in generally the same geographic region as *P. ramorum*; therefore, these *Phytophthora* species are associated with the nursery stock pathway.

- The historical introduction of *P. ramorum* into California is linked to the nursery trade (Ivors et al. 2006; Mascheretti et al. 2008). *Phytophthora ramorum* was introduced into the USA and Europe via imported *Camellia, Rhododendron* or *Viburnum* species nursery stock (Brasier 2007); therefore, the nursery trade is the most likely pathway for the introduction of *P. ramorum* (Ivors et al. 2006; Grünwald et al. 2008a; Prospero et al. 2009) at both continental and worldwide scales. Consequently, trade in nursery stock of infected hosts is likely to result in the introduction of *Phytophthora* species into Australia.
- *Phytophthora kernoviae, P. nemorosa, P. pseudosyringae* and *P. ramorum* have a significant aerial component to their life cycle (Davidson et al. 2005; 2008; Martin et al. 2012). Some plants are hosts to multiple *Phytophthora* species, thus increasing the probability of inadvertently introducing different *Phytophthora* species into new areas.
- *Phytophthora ramorum* is heterothallic and requires two opposite mating types (A1 and A2) for sexual recombination (Ivors et al. 2006). Initially, only single mating types were identified in Europe (A1 mating type) and the United States (A2 mating type), indicating that *P. ramorum* was introduced into these countries (Ivors et al. 2006). More recently, both mating types have been identified in the United States and Europe and it is speculated that the commercial plant trade may have lead to multiple introductions of the pathogen (Werres & De Merlier 2003; Ivors et al. 2006; Mascheretti et al. 2008).
- *Phytophthora ramorum* infects many different plant species in nurseries (Werres et al. 2001; Rizzo et al. 2002b; Davidson et al. 2003b). Symptoms include foliar necrosis, branch die-back, and lethal stem infection. The most common nursery stock hosts include several species and varieties within the genera *Camellia*, *Rhododendron* and *Viburnum* (Huberli & Garbelotto 2012).
- Global trade and the associated movement of ornamental plant material across borders has introduced *P. ramorum* into new areas (Ivors et al. 2006; Mascheretti et al. 2008; Goss et al. 2011; Tsopelas et al. 2011; Alexander 2012). *Phytophthora ramorum* has primarily been introduced on *Camellia japonica, Kalmia latifolia, Leucothoe* species, *Pieris formosa* var. *forrestii, P. japonica, Rhododendron* species, *Syringa vulgaris*, *Taxus baccata* and *Viburnum* species (Werres & De Merlier 2003; Husson et al. 2007).
  - *Phytophthora ramorum* was introduced from one infected nursery (on *Camellia* species) to 21 states in the USA (Cave et al. 2008); with infected *Rhododendron* species from Belgium to Greece (Tsopelas et al. 2011); and from Germany and the Netherlands into Norway (Sundheim et al. 2009). Therefore, the movement of nursery plants is the main pathway for the introduction of this pathogen into new areas (Alexander 2012).
- The high degree of genetic similarity between *P. nemorosa* and *P. pseudosyringae* and the lack of genetic structure within their range in western USA are consistent with the hypothesis of relatively recent introductions to the western USA (Linzer et al. 2009).

Ability of the pest to survive transport and storage

- *Phytophthora ramorum* is very likely to survive during transport and storage since the primary conditions for survival are fulfilled by the presence of the live host plant and associated environmental conditions. Planting material is grown, packaged and shipped to areas conducive to their survival. The handling of nursery stock may not be detrimental to the survival of this pathogen. General transport conditions for potted plants range from 10 °C to 18 °C and 85 to 90 percent relative humidity (McGregor 1987). *Phytophthora ramorum* has an optimum temperature range for survival and reproduction of 18 °C to 25 °C, with a minimum growth temperature of 2 °C and a maximum growth temperature of 26 °C to 30 °C (Werres et al. 2001). Pathogen growth is therefore likely to continue during transport within infected plant tissues.
- *Phytophthora ramorum* produces sporangia on foliage and chlamydospores inside the infected host tissue (Pogoda & Werres 2004; Parke & Lewis 2007), which are unlikely to be dislodged during handling and shipping of nursery stock. Sporangia produced on infected tissues are able to survive a range of temperatures between 0 °C and 25 °C (Turner et al. 2005; Turner & Jennings 2008). Therefore, it is also likely that sporangia on host tissues will survive under most transport conditions.
- The survival of *P. ramorum* in plants during transportation is demonstrated in the USA, where *P. ramorum* infected nursery stock from several states was traced to infected nurseries in California (Cave et al. 2008). In Europe, *P. ramorum* was introduced to Majorca, Spain via a shipment of infected *Rhododendron* species, and many of the infections found in nurseries in Europe could be traced to plants shipped from other nurseries (Davidson & Shaw 2003; Lilja et al. 2007; Rytkönen et al. 2007).
  - Since the first discovery in Norway in 2002, *P. ramorum* has been intercepted at the Norwegian border on *Pieris japonica, Rhododendron* species and *Viburnum* species imported from European countries (Sundheim et al. 2009). The numerous interceptions of *P. ramorum* in the plant trade between European countries demonstrate the ability of this fungus to survive transport, storage handling and shipping of nursery stock (Figure 2).

Figure 2 Interception of *Phytophthora ramorum* in Europe



Arrow thickness is proportional to the number of interceptions; arrow direction shows the direction of the interception. Source: EFSA (2011).

Ability of the pest to survive existing pest management procedures

- *Phytophthora* species are, in general, difficult to control. Fungicidal treatments in nursery stock against *P. ramorum* are more effective as 'protectants' than as 'curatives' as they will not exclude the pathogen from already infected plants (Tjosvold et al. 2005; 2008). Therefore, fungicides used in the nursery will suppress symptoms caused by *Phytophthora* species but not cure infected plants.
- The use of fungicides may lower infection rates but may not completely eliminate the pathogen. This assumption is supported by the detection of *P. ramorum* in consignments that were treated to eradicate *P. ramorum.* Furthermore, the use of fungicides may also reduce the efficacy of detection in consignments. For this reason, the removal of *P. ramorum* from the consignment by treatment is not considered an appropriate measure to mitigate the risk posed by *Phytophthora* species.
- No treatment can guarantee the removal of *P. ramorum* from the consignments, with the exception of heat treatments (Garbelotto 2003; Aveskamp & Wingelaar 2005; Swain et al. 2002; 2006). Heat treatments were considered an effective option for the sanitation of *P. ramorum* plant material; however, these kinds of treatments can only be applied on non-living commodities.

Likelihood of distribution (transfer to a susceptible host)

The likelihood that the *Phytophthora* species will be distributed within Australia in a viable state with imported nursery stock (including ornamental plants and propagative material) and be transferred to a suitable host is **HIGH**.

Ability of the pest to move from the pathway to a suitable host

- *Phytophthora ramorum* arriving in Australia with imported nursery stock does not need to move from the import pathway to a suitable host as the pathogen is already within a suitable host. Mycelium, sporangia, zoospores and chlamydospores have the potential to be associated with infected plants (Parke et al. 2002a; Davidson et al. 2005; Turner et al. 2005).
- Nursery stock of known *Phytophthora* hosts is imported specifically for the purpose of propagation and can be a significant investment for importers. Infected nursery stock is therefore likely to be grown directly into suitable habitats at multiple locations throughout Australia. The distribution of infected nursery stock commercially will facilitate the distribution of *Phytophthora* species.

Distribution of the imported commodity in the PRA area

- Infected nursery stock may be distributed to orchards, nurseries or retail shops and for backyard and amenity plantings where the fungus may continue proliferating within the host.
- *Phytophthora ramorum* has a very wide host range and the conditions in nurseries are likely to favour the dispersal of the pathogen and infection of new host plants within nurseries.
- Sporulation of *Phytophthora* species will help transfer propagules to nearby plants. *Phytophthora ramorum* and *P. kernoviae* produce sporangia on the asymptomatic infected leaves of a range of hosts including *Crataegus, Laurus, Quercus, Rhododendron, Rosa* and

Smilax species (Brasier 2007). Therefore, in nursery trade networks, *Phytophthora* species are highly likely to be transferred to and infect nearby host plants.

- *Phytophthora* species require moist conditions, and nursery environments provide these ideal conditions through dense canopies, irrigation and fertilisation (Dart et al. 2007; Schwingle et al. 2007). Wet conditions are required for spore production and successful infection; sporangia and zoospores develop on the leaf surface of susceptible leaves and twigs following prolonged wetting. The sporangia give rise to zoospores, which are biflagellate spores that can swim in water. Windblown rain, direct contact of infected leaves and run off from leaves are the main ways that the pathogen is disseminated from plant to plant.
- Infected nursery stock is unlikely to be grown in isolation, providing greater opportunities for the transfer of *Phytophthora* species to other plants. Production of sporangia on infected tissues (Parke et al. 2002a; Davidson et al. 2005; Turner et al. 2005) serves as the primary inoculum, transferring the pathogen to nearby plants under appropriate environmental conditions.
- *Phytophthora ramorum* would need to survive transportation and storage within Australia. Nursery stock is expected to be maintained at moderate temperatures and humidity levels to ensure nursery stock survival, so a portion of infected nursery stock that enters the country is likely to reach areas of host abundance.
- As nursery stock may not display obvious symptoms of *Phytophthora* infection, there is a risk that infected plant material would be used for propagation. Material from infected plants may be used for planting directly at multiple locations in Australia. Asymptomatic plants may also be overlooked and sold to commercial users and households.

Risks from by-products and waste

- Although the intended use of nursery stock is for propagation, all imported material would be grown under ideal conditions and waste material may be generated. Whole or parts of the plants may be disposed of at multiple locations throughout Australia as green waste or retail waste.
- Green waste containing infected host material may serve as a source of spores, even with green material dried for several months. On some plant tissue, such as *Rhododendron* species leaves, *P. ramorum* will still sporulate upon wetting (Davidson & Shaw 2003). *Phytophthora ramorum* produces sporangia and zoospores, which could disperse via rain-splash to host plants.
- *Phytophthora ramorum* has a wide host range (Hüberli & Garbelotto 2012) and these hosts are widespread in cities, towns and horticultural production areas throughout Australia and grown in gardens, parks, streetscapes and native plant communities in parts of Australia.
- *Phytophthora ramorum* may also produce chlamydospores, which will help the pathogen survive extreme temperatures, dryness and other harsh conditions. Chlamydospores are formed in plant tissues and leaves, and can survive in the soil. Soil-borne chlamydospores can survive long periods (Fichtner et al. 2009) and give rise to new sporangia that are splashed or carried to infect above-ground plant parts.
- A relatively high proportion of household and retail waste would be managed through regulated refuse collection and disposal services. A proportion of garden waste would be

managed through green waste centres. Unlike managed waste, garden waste is more likely to be retained in urban and semi-urban environments for a period of time before being disposed of at green waste centres. Managed waste will remove *Phytophthora* species from the household and environment, reducing the likelihood that susceptible plants will be exposed to these pathogens.

- Studies have demonstrated that temperatures of 37.5 °C to 40 °C are lethal to *P. ramorum* hyphae within several hours, and that 42.5 °C to 50 °C is lethal within a matter of minutes (Browning et al. 2008). These extreme temperatures will not commonly be encountered in nature; however, composting waste material is likely to generate high temperatures that can be lethal to a range of pathogens (Noble & Roberts 2004). Studies indicate that *P. ramorum* in green waste mulch is killed in compost after being held at 55 °C for two weeks (Davidson & Shaw 2003).

Overall likelihood of entry (importation x distribution)

The overall likelihood of entry of the *Phytophthora* species is determined by combining the likelihood of importation with the likelihood of distribution using the matrix of rules for combining qualitative likelihoods (Table 2).

- The likelihood that the *Phytophthora* species will enter Australia with imported host plant propagative material from countries where these pathogens are present and transferred to a suitable host is **HIGH.**

4.1.2 Likelihood of establishment

The likelihood that the *Phytophthora* species, having entered on imported host plant propagative material, will establish within Australia, based on a comparison of factors in the source and destination areas considered pertinent to its survival and reproduction is **HIGH**.

Availability of suitable hosts, alternative hosts and vectors in the PRA area

- Association with the host will facilitate the establishment of the *Phytophthora* species, as these pathogens are already established with, or within, a suitable host. As host plant material is likely to be maintained in places with similar climates to the area of production, climatic conditions are expected to favour the pathogen's establishment.
- Nursery stock is intended for ongoing propagation or horticultural purposes and is deliberately introduced, distributed and aided to establish. This material will enter and then be maintained in a suitable habitat, potentially in substantial numbers and for an indeterminate period. Therefore, the introduction and establishment of plants from imported propagative material in essence establishes those pathogens associated with the propagative material.
- *Phytophthora ramorum* is a generalist plant pathogen (Hüberli & Garbelotto 2012) that has an extremely broad host range. Hosts include many important shrubs and trees of ornamental or environmental significance. These natural hosts are widespread in cities, towns and horticultural production areas throughout Australia and in the natural environment. The availability of host species and a climate conducive to infection will help establish *Phytophthora* species in Australia.

- The type of hosts that are affected varies between countries, environmental conditions and type of pathogen causing the infection (Sundheim et al. 2009). Based on symptoms, *P. ramorum* hosts can be categorised as 'canker hosts' or 'leaf and twig hosts' (Davidson et al. 2003b). The pathogen is polycyclic on most leaf and twig hosts (Davidson et al. 2003a, b; 2005) and while the infection on leaf and twig hosts is rarely fatal, it can serve as a reservoir for the pathogen (Parke et al. 2002b, c; Rizzo et al. 2002a). Leaf and twig hosts are present in parts of Australia and therefore will help establish *P. ramorum* in Australia.
- Sporangia and chlamydospores are produced abundantly on several foliar and dieback hosts, including *Umbellularia californica* (Davidson et al. 2002b), *Rhododendron* species and *Kalmia latifolia* (DEFRA 2004). Foliar hosts including *Rhododendron* species and *U. californica* play an important role in building up *P. ramorum* inoculum. The availability of susceptible and sporulating hosts will help establish *P. ramorum* in Australia and can lead to the infection of many other native plant species in Australia.

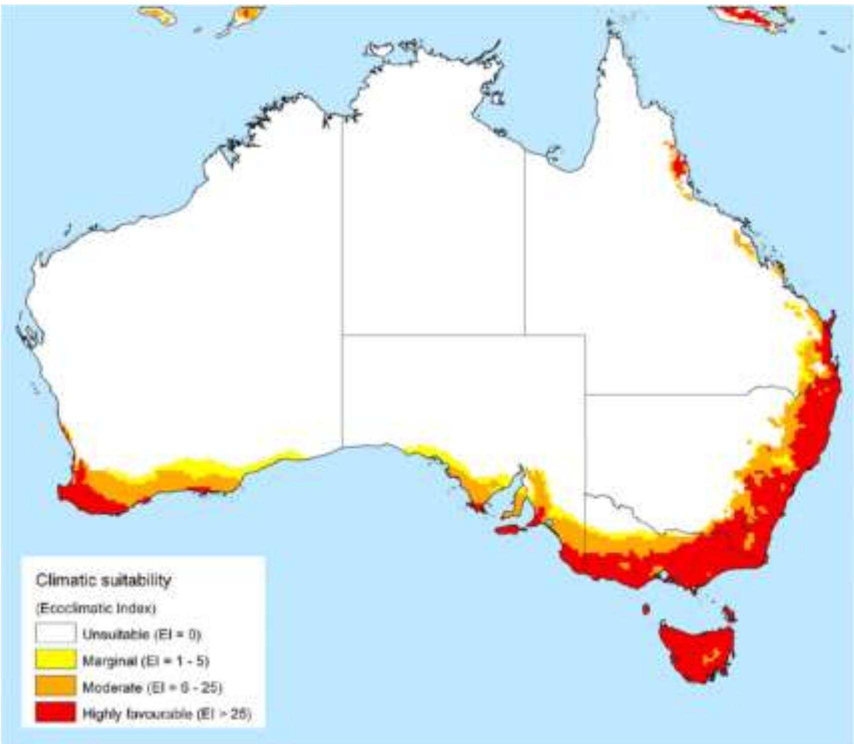
- Several host genera of *P. ramorum* are widely distributed in temperate and Mediterranean regions, and grow in gardens, parks, streetscapes and native plant communities in parts of Australia (Appendix A). They include genera that are cultivated (*Arbutus, Quercus, Rhododendron* and *Viburnum* species), naturalised (*Acer, Lonicera* and *Salix* species) and native (*Adiantum, Cinnamomum, Dryopteris, Eucalyptus, Euonymus, Gaultheria, Ilex, Nothofagus, Pittosporum, Rhododendron* and *Rubus* species).
  - Several Australasian plant species, including *Eucalyptus haemastoma, Griselinia littoralis* and *Pittosporum undulatum* are known natural hosts of *P. ramorum* (Hüberli et al. 2006). These species are widespread in parts of Australia and will act as foliar sporulating hosts, thereby helping *P. ramorum* to establish in Australia.
- Infestations by *P. ramorum* are virtually invisible for variable periods of time, depending on the affected ecosystem. If a foliar host is driving the epidemic (for example, bay laurel or *Rhododendron* species), there may be a long lag phase between infection and symptom expression as symptoms are hard to detect on foliar hosts. Symptoms on these foliar hosts often manifest as small lesions, which are not very visible and can be easily confused with symptoms caused by other agents (Wickland et al. 2008). In addition, infected hosts such as *Rhododendron* species can be asymptomatic (Denman et al. 2009). These characteristics will help establish *Phytophthora ramorum* in Australia.

Suitability of the environment

- *Phytophthora* species (*P. kernoviae, P. nemorosa, P. pseudosyringae* and *P. ramorum*) have established in areas with a wide range of climatic conditions (Map 3). The current reported distribution of *Phytophthora* species (Ivors et al. 2006; Mascheretti et al. 2008) suggests an ability to establish in new environments. There are similar climatic regions in parts of Australia that would be suitable for the establishment of these *Phytophthora* species; therefore, *Phytophthora* species are likely to be able to establish in Australia.
- Foliar hosts play an important role in building up inoculum of these *Phytophthora* species. The availability of susceptible and sporulating hosts will help establish these *Phytophthora* species in Australia and can lead to infection of many other native plant species.

- The origin of *P. ramorum* is not known and is difficult to determine; however, this species is now established in Belgium, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, India, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland, the UK and the USA (Denman et al. 2009; Gomes & Amaro 2009; Sansford et al. 2009; EPPO 2012; FERA 2012; Mathew & Beena 2012). The climatic regions across this range are diverse and there are similar climatic regions in parts of Australia that would be suitable for the establishment of *P. ramorum* (Map 4) (Ireland et al. 2013).

Map 4 Areas suitable for the establishment of *Phytophthora ramorum* in Australia



Source: Ireland et al. (2013)

- Climate is an important factor that affects the establishment of *P. ramorum*. The pathogen is regarded as a cool temperate organism (Kliejunas 2000). Optimum temperature for growth of *P. ramorum* is around 20 °C with a minimum growth temperature of 2 °C and a maximum growth temperature of 26 °C to 30 °C (Werres et al. 2001). Infection does not occur below 10 °C and above 30 °C. Such conditions exist in parts of Australia; therefore, if introduced, these *Phytophthora* species are likely to establish in Australia.
- Moisture is an essential factor in the survival and sporulation of *P. ramorum*. The duration, frequency and timing of rain events, during the winter months, plays a key role in inoculum production and the infection cycle (Davidson et al. 2008). The infection of foliar tissue requires cool temperatures and free water. Infection of *Umbellularia californica* leaves was highest at 18 °C and required a minimum of six to 12 hours of free water (Garbelotto et al. 2003). Sporangia formed on infected tissues are able to survive a range of temperatures between 0 °C and 25 °C (Turner et al. 2005; Turner & Jennings 2008). These conditions exist in parts of Australia; therefore, *P. ramorum* may establish in areas of Australia where suitable environmental conditions are available.

  - *Phytophthora ramorum* requires a moist environment to actively grow and reproduce (Tjosvold et al. 2005). Wet conditions are required for spore production, successful infection and subsequent establishment. These conditions exist in parts of Australia.
  - The current distribution of *P. ramorum* indicates that it survives well in the Mediterranean coastal fog belts of California (Rizzo et al. 2002b), as well as in the temperate oceanic climate of Cornwall and Wales in the south-west of England (Brasier et al. 2004c). Such environmental conditions exist in parts of Australia.
- *Phytophthora ramorum* is moderately adaptable (Sansford et al. 2009). The different lineages of the pathogen in Europe and the USA indicate that *P. ramorum* could readily evolve. The ability to adapt would be enhanced by sexual reproduction, but even in the absence of sexual reproduction, genetic recombination may occur through somatic hybridization (Brasier 2008).
- Small populations of *P. ramorum* are likely to establish in Australia. The repeated findings of *P. ramorum* in *Rhododendron* species in parks in Europe support the view that small populations can become established and survive if the climate is suitable and susceptible plants are available.

The reproductive strategy and survival of the pest

- *Phytophthora* species are capable of reproducing sexually and asexually. Sexual reproduction can be homothallic (*P. kernoviae, P. nemorosa* and *P. pseudosyringae*) or heterothallic (*P. ramorum*). During the asexual life cycle, *Phytophthora* species are able to differentiate into different life stages including mycelium, sporangium, zoospore and chlamydospores (Savidor et al. 2008).
- *Phytophthora ramorum* has a flexible and adaptive reproductive strategy that most likely would favour establishment.
  - *Phytophthora ramorum* produces vegetative hyphae and four types of spores: sporangia, zoospores, chlamydospores (asexually formed resting spores) and oospores (sexually formed resting spores). All spore types, except oospores, are found in nature (Werres et al. 2001; Parke et al. 2002a; Davidson et al. 2003b).
  - Sporangia and zoospores develop on the surface of susceptible leaves and twigs following prolonged wetting. Sporangia can germinate directly or produce motile zoospores that initiate infection. Chlamydospores are the primary survival stage of the pathogen, and are produced in infected leaves, shoots and bark, in both phloem and xylem tissues (Parke et al. 2008). The asexual life cycle is responsible for rapid multiplication and establishment of the pathogen in the field.
  - *Phytophthora ramorum* is a heterothallic species that requires two mating types A1 or A2 (Werres et al. 2001; Werres & Kaminski 2005) to reproduce sexually. The A1 mating type is found predominantly in Europe and the A2 predominantly in the USA (Ivors et al. 2004). However, recently a few A2 mating types have been found in Europe and a limited number of A1 mating types have been identified in nursery stock in the USA and Canada (Hansen et al. 2003b; Werres & De Merlier 2003).
  - Oospores have so far not been detected in nature, but in the laboratory oospores can be produced in *Rhododendron* species stems (Werres & Zielke 2003) and *in vitro* (Hansen

et al. 2003a). The production of oospores could favour establishment since oospores are likely to facilitate long-term survival. The production of oospores may also result in sexual reproduction, allowing genetic recombination to occur and to create new, potentially more virulent strains capable of exploiting new habitats and host species (Tjosvold et al. 2005).

- Differences in aggressiveness, growth rate, colony type and sporangia morphology have been observed between the different lineages; however, DNA profiling studies have provided evidence that the European and North American isolates represent distinct populations of *P. ramorum*, and not distinct species (Ivors et al. 2004; 2006; Martin 2008; Grünwald et al. 2008b).
- The managed environment in nurseries, garden centres and private gardens are all favourable for the establishment and survival of *P. ramorum*, as host plants are abundantly available. The plants are closely placed and sprinkler irrigation favours the pathogen's multiplication and local dispersal. *Phytophthora ramorum* requires moist conditions, and nursery environments provide ideal conditions through dense canopies and irrigation (Dart et al. 2007; Schwingle et al. 2007). Nursery trade networks, which are common between Australian nurseries, favour a wider establishment of *P. ramorum*.
- *Phytophthora ramorum* has an aerial phase (Sansford et al. 2009) as well as a soil phase (Shishkoff 2007). During the soil phase, *P. ramorum* can survive for long periods of time in the soil and leaf litter; therefore, once introduced into nursery networks, gardens and parks, establishment of *P. ramorum* is favoured by the soil-borne phase. *Phytophthora ramorum* can survive at least three years in parks in the UK and 1.5 years in soil in the Netherlands (Sansford et al. 2009). *Phytophthora kernoviae* can persist for at least a year in leaf litter (Sansford 2008).
- *Phytophthora* species (*P. kernoviae*, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum*) have successfully established in areas outside their original distribution. These *Phytophthora* species have demonstrated their ability to colonise new hosts and to produce high amounts of inoculum. Furthermore, host material and suitable climatic conditions are available in parts of Australia; therefore, these *Phytophthora* species may establish in Australia after entry with nursery stock.
- Chlamydospores of *P. ramorum* have been observed in/on leaves (Tooley et al. 2004; Davidson et al. 2005), twigs, stems (Pogoda & Werres 2004; Lewis & Parke 2006; Parke et al. 2007a, b) and fruit (Moralejo et al. 2006). Chlamydospores in potting medium, sand and soil are long-lived at moderate temperatures (Colburn et al. 2005; Linderman & Davis 2006a; Fichtner et al. 2007a; Shishkoff 2007). However, the survival of *P. ramorum* in colonised plant tissues (attached leaves and stems, and decomposing leaves in contact with soil) at extreme temperatures is unlikely to occur. For example, when *P. ramorum* was present in infected *Rhododendron* species leaves, in the form of chlamydospores and perhaps hyphae, survival at 35 °C declined within two days, with no survival observed by the fourth day (Tooley et al. 2008). In addition, studies demonstrate that temperatures of 37.5 °C to 40 °C are lethal to *P. ramorum* hyphae within several hours and temperatures of 42.5 °C to 50 °C are lethal within a matter of minutes (Browning et al. 2008); however, such extreme temperatures rarely occur under natural conditions.

- Temperature and moisture are crucial factors that determine the survival and sporulation of most pathogens, including *Phytophthora* species (Erwin & Ribeiro 1996).
  - Bay laurel trees play a crucial role in the reproduction and survival of *P. ramorum* in coastal California forests by supporting sporulation during the rainy season and by providing a means for the pathogen to survive the dry, Mediterranean summer (Davidson et al. 2011). Foliar hosts present in Australia will not only support sporulation during the rainy season but will also provide a means of survival during the dry season.
- Newly established populations of *Phytophthora* species may go undetected for years; for example, *P. ramorum* was first noted in California in 1995 (Garbelotto et al. 2001) but researchers suggest that the pathogen was introduced at least five years before the first detection (Rizzo & Garbelotto 2003).

4.1.3 Likelihood of spread

The likelihood that the *Phytophthora* species, having entered on host plant propagative material and established, will spread in Australia, based on a comparison of those factors in the source and destination areas considered pertinent to the expansion of the geographic distribution of the pest is **HIGH**.

The suitability of the natural or managed environment for natural spread

- *Phytophthora ramorum* is exotic and has spread from an unknown area to Europe and the USA (Ivors et al. 2006; Brasier 2007; Mascheretti et al. 2008), indicating that the pathogen is able to spread naturally.
- *Phytophthora ramorum* was first discovered in Germany and the Netherlands (Werres et al. 2001) and then, shortly after, in the USA (Rizzo et al. 2002b). Since then, *P. ramorum* has spread throughout Europe, the USA and Canada. There are similarities in the natural and urban environments of these areas with those in Australia, which suggests that *P. ramorum* could spread in Australia.
- Host plants that support the spread of *P. ramorum* are widespread in cities, towns and horticultural production areas throughout Australia and in the natural environment. For example, *Eucalyptus* species hosts are widespread in Australia.
- Foliar hosts, including many Ericaceae, are common in Australia. These hosts play a particularly important role in the production of infectious sporangia and the development of epidemics (Garbelotto et al. 2003; Rizzo & Garbelotto 2003; Tooley et al. 2004). Foliar hosts also support the development of chlamydospores, the primary survival stage of the pathogen.
- The managed environment in nurseries, garden centres and private gardens are all favourable for the spread of *P. ramorum* as host plants are abundantly available. The plants are closely placed and sprinkler irrigation favours pathogen multiplication and local spread. *Phytophthora ramorum* requires moist conditions and nursery environments provide these ideal conditions through dense canopies and irrigation (Dart et al. 2007; Schwingle et al. 2007). Nursery trade networks, which are common between Australian nurseries, favour a wider spread of *P. ramorum*.

- *Phytophthora ramorum* needs a susceptible foliar host for inoculum build up and suitable climatic conditions in order to infect and initiate lesions on stems of trees. Stem infections have been reported only in forests where bay laurel or *Rhododendron ponticum* is a significant understorey species. Owing to its high susceptibility and ability to support high levels of sporulation, *R. ponticum* plays a key role in the spread of *P. ramorum* into natural and semi-natural environments and the subsequent spread to trees (Webber 2008). *Arbutus unedo*, *Quercus ilex*, *Rhamnus alaternus*, *Vaccinium* species and *Viburnum tinus* also support abundant sporulation and might enable the spread of *P. ramorum* to trees (Goheen & Frankel 2009).
- After establishment, *P. ramorum* can spread both independently and in association with infected nursery stock. Independent spread is facilitated by the production of spores on infected tissues (Hansen et al. 2008), which become air-borne during rain and could spread through air currents (Davidson et al. 2002a; Judelson & Blanco 2005). This natural dispersal could play a major role in spreading the pathogen within a plant and from plant to plant (Davidson et al. 2002a; Judelson & Blanco 2005).
- *Phytophthora ramorum*, and the other *Phytophthora* species under review, produces caduceus sporangia, an adaptation evolved for aerial dispersal (Erwin & Ribeiro 1996). The natural spread of *P. ramorum* will depend on a number of factors including spore production, spore dispersal, pathogen survival, host availability and climatic conditions (Sansford et al. 2009). The natural spread of *P. ramorum* is facilitated by the movement of water (rain, runoff, streams, rivers and irrigation water), animals and aerial dissemination (of sporangia, zoospores and possibly chlamydospores). Strong winds, during heavy rains may disseminate the detached sporangia over great distances (Hansen et al. 2002; Rizzo et al. 2005).
- Different dispersal mechanisms may lead to short or long distance dispersal. Typical dispersal distances by rain-splash are in the order of 10 to 20 meters, depending on topography and the plant community structure (Chastagner et al. 2008; Mascheretti et al. 2008). In parts of Australia, where climate events are favourable and there is an abundance of continuous hosts, natural spread could be significantly more rapid. *Phytophthora ramorum* propagules (sporangia, zoospores) disperse 10 meters and can disperse up to 25 meters in wind-driven rain (Davidson et al. 2002a; Rizzo et al. 2005). In Oregon, about half of the new *Phytophthora* infections each year occur within 100 meters of trees killed the previous year, but long distance dispersal up to three kilometres may occur in storm winds (Rizzo et al. 2005).
- Short distance spread of *Phytophthora* species occurs on a yearly basis and is normally within a few kilometres. Long distance spread (through infected nursery stock) occasionally occurs, and seems to be linked to favourable weather conditions for the pathogen (EFSA 2011).
  - In nurseries, spread is linked to water-borne spread (Garbelotto & Rizzo 2005), and is often limited to adjacent plants. *Phytophthora ramorum* requires moisture to complete its life cycle; wet environments in the nursery setting favour spore production, dispersal, germination and infection. Therefore, the humid conditions in nurseries that allow moisture to remain on plant leaves and stems, will favour the spread of the pathogen.
  - Medium distance movement of sporangia is linked to turbulent movement and only occurs in the presence of winds strong enough to pick up sporangia (Mascheretti et al.

2008). Sporangia can be spread one to five kilometres from the source (Mascheretti et al. 2008).

- Infected nursery stock is unlikely to be grown in isolation; thereby providing a greater opportunity for the spread of *Phytophthora* species to other plants. The production of sporangia on infected tissues (Hansen et al. 2008) serves as the primary inoculum, spreading the pathogen to healthy leaves and shoots under appropriate environmental conditions (Hüberli et al. 2003a). However, sporangia may not survive long distance transport due to desiccation (Ristaino & Gumpertz 2000).
- Asymptomatic roots of infected *Rhododendron* species harbour chlamydospores of *P. ramorum* (Riedel et al. 2009). Both *P. ramorum* and *P. kernoviae* are capable of sporangial production on asymptomatic infected leaves and fruits of a range of hosts including *Crataegus, Laurus, Quercus, Rhododendron*, *Rosa* and *Smilax* species (Denman et al. 2008). Therefore, visually healthy plants may harbour a sporulating pathogen in the roots or foliage and bare-rooted shipping stock will help spread the pathogen into new areas.
- Genotypes of *P. ramorum* have been spread via the nursery stock trade from Europe to North America (Goss et al. 2011). In Canadian nurseries, the NA1, NA2 and EU1 genotypes have been found. NA2 is the most common lineage whereas NA1 is rare. In addition, the EU1 lineage is frequently detected in Canada (Goss et al. 2011) indicating that EU1 has spread from Europe to North America (Goss et al. 2011).
- The rapid spread of *P. ramorum* during the early 2000s, in Europe and in the USA is related to the movement of infected nursery stock from infested regions into new areas (Brasier 2007; Cave et al. 2008; Alexander 2012). Similarly, *P. ramorum* will spread within Australia, if it is established.
- Certain hosts play an important role in the spread of *P. ramorum* in the ecosystem. *Phytophthora ramorum* sporulates (production of deciduous sporangia) profusely during favourable conditions on bay laurel trees, with less abundant sporulation on other hosts such as tanoak twigs and redwood needles. The presence of bay laurel (a preferred sporulating host) plays an important role in the epidemiology. For example, the presence of infected bay laurel leaves is strongly correlated with stem cankers on *Quercus agrifolia* (Kelly & Meentemeyer 2002; Rizzo & Garbelotto 2003); therefore, foliar infections of bay laurel generally lead to infection of oaks in Californian forests (Rizzo & Garbelotto 2003). Foliar hosts (supporting spore build up) are present in natural and urban environments of Australia, which suggests that *P. ramorum* could spread in Australia.
- The presence of a foliar host that can support massive spore build up increases the disease intensity, resulting in the spread of the pathogen to other hosts growing in close proximity. For example, in Californian forests of tanoak and bay laurel trees, the high mortality of tanoaks caused by *P. ramorum* is increased with the presence of bay laurels (Cobb et al. 2010). Bay laurels, while not lethally affected by *P. ramorum*, support sporulation during the rainy season and provide a means for the pathogen to survive the dry Mediterranean summer (DiLeo et al. 2009). A shift in species composition is likely to lead to an increased production of inoculum (Cobb et al. 2010).
- Increased abundance and density of a reservoir host that supports high sporulation will increase the probability of *P. ramorum* occurrence. A similar relationship with bay laurel was noted for *P. nemorosa* and *P. pseudosyringae* (Maloney et al. 2005; Murphy & Rizzo 2006;

Wickland & Rizzo 2006). While the probabilities of all three pathogens increases with more bay laurels present, they differ in their responses to various climatic variables, including rain and temperature (Murphy et al. 2008).

- In ecosystems in parts of Australia where *Rhododendron* species are less abundant or absent, other plant species may take on the equivalent role and support abundant sporulation by *P. ramorum*. Several species other than *Rhododendron* species have the potential to support moderate to high levels of sporulation (Moralejo et al. 2006). Species of *Vaccinium* also support high levels of sporulation similar to those observed on bay laurel (Webber 2008); therefore, the presence of such hosts will help spread *P. ramorum* in Australia.
- The current knowledge of the host range of *P. ramorum* based on naturally infected plants and inoculation studies suggests that the Australian flora will be highly susceptible to the pathogen, both in natural and landscaped areas.

Presence of natural barriers

- *Phytophthora ramorum* has the potential for natural and human mediated spread. Natural spread of *P. ramorum* is through air-borne inoculum (Davidson et al. 2005). Sporangia are primarily dispersed short distances by rain-splash; therefore, its rate of non-facilitated spread may generally be limited (Moralejo et al. 2006; Mascheretti et al. 2008; Hansen 2008). However, strong winds during heavy rains may disseminate the detached sporangia over greater distances (Hansen et al. 2002; Rizzo et al. 2005).
- Hosts of *P. ramorum* are present in many parts of Australia. Host plants that support the spread of *P. ramorum* are widespread in cities, towns and horticultural production areas throughout Australia and in the natural environment. Hosts include important nursery and landscape species including *Arbutus, Calluna*, *Camellia, Choisya, Cornus, Garrya, Griselinia, Hamamelis*, *Ilex, Kalmia, Laurus*, *Leucothoe, Lonicera*, *Magnolia, Michelia, Osmanthus, Parrotia, Photinia, Pieris, Rhododendron, Ribes, Syringa*, *Taxus*, *Umbellularia*, *Vaccinium* and *Viburnum* species (Werres et al. 2001; Tooley et al. 2004; Lane et al. 2007). Natural barriers such as arid areas, mountain ranges, climatic differentials and possible long distances between suitable hosts in parts of Australia may prevent long-range natural spread of this pathogen.
- The *Phytophthora* species would be climatically limited by temperature for growth and moisture requirements for zoosporic infection. For example, the temperature thresholds (minimum, optimum and maximum) for *P. kernoviae* infections are 3 °C, 18 °C, and 26 °C, respectively (Brasier et al. 2005). Similarly, *Phytophthora ramorum* has an optimum temperature range of 18 °C to 25 °C for pathogen growth (Werres et al. 2001) and requires moisture for at least 12 hours for infection to occur (Hüberli et al. 2003a). *Phytophthora ramorum* infection of foliar tissue requires cool temperatures and free water; for example, infection of bay laurel leaves was highest at 18 °C, and required a minimum of six to 12 hours of free water (Garbelotto et al. 2003).
- *Phytophthora* species (*P. kernoviae, P. nemorosa, P. pseudosyringae* and *P. ramorum*) occupy similar host and geographical ranges as well as the same forest communities and ornamental nurseries (Webber 2008; Yakabe et al. 2009; Grünwald et al. 2011); however, they differ in their specific ecological niches (Murphy et al. 2008). Therefore, the spatial distribution of different ecological niches may affect the natural spread of these pathogens.

- *Phytophthora* species presence is highly related to forest structure and climate (Murphy et al. 2008). For example, in North America, while the probability of these pathogens increases with more bay laurel hosts present, the pathogens differ in their responses to various climatic variables, including rain and temperature (Murphy et al. 2008).
  - The presence of foliar hosts; for example, bay laurel, combined with higher winter or spring rain and higher minimum annual temperatures, are conditions more suitable for *P. ramorum.* Similarly, the abundance of foliar hosts, lower annual maximum temperature or lower annual minimum temperature and higher winter rain areas will support the spread of *P. nemorosa*. *Phytophthora pseudosyringae* is associated with drier plant communities such as coastal live oak forest types (Murphy et al. 2008).
  - The abundance and presence of foliar hosts, which support high levels of sporulation, increases the occurrence of *P. nemorosa, P. pseudosyringae* and *P. ramorum* (Maloney et al. 2005; Murphy & Rizzo 2006; Wickland & Rizzo 2006).
- Indirect and direct evidence (Davidson et al. 2005; Mascheretti et al. 2008) indicates that the natural dispersal of *P. ramorum* is mostly at a relatively small scale (one to 10 meters); however, infection only occurs when water is present on plant surfaces, indicating that zoospore release is a necessary step in the infection process. The optimum temperature for the infection process is reported to be 20 °C (Garbelotto et al. 2003; Davidson et al. 2005; Hayden et al. 2008).
- Long-distance dispersal of *P. ramorum* by natural means includes movement by aerial dissemination (of sporangia, zoospores and possibly chlamydospores) through wind driven rain and turbulent air. Such long-distance spread could transport the pathogen up to several kilometres away; for example, this type of dissemination is considered to be responsible for the spread of the A2 mating type of the North American clonal lineage (NA1) in California and Oregon (Hansen 2008).
- However, the frequency of such long-distance dispersal events via wind-driven rain or turbulent air will most likely depend on the frequency of storm events, the amount of infected plants at the source, and the presence of hosts at the sites where inoculum is deposited. Most infections outside nurseries have been attributed to human-mediated movement of infected plants (Jeger et al. 2007). There is evidence for natural spread from nurseries to nearby (within one kilometre) semi-natural environments (Jeger et al. 2007). The large sporangia can be picked up by strong winds and deposited one to three kilometres from the source (Mascheretti et al. 2008).

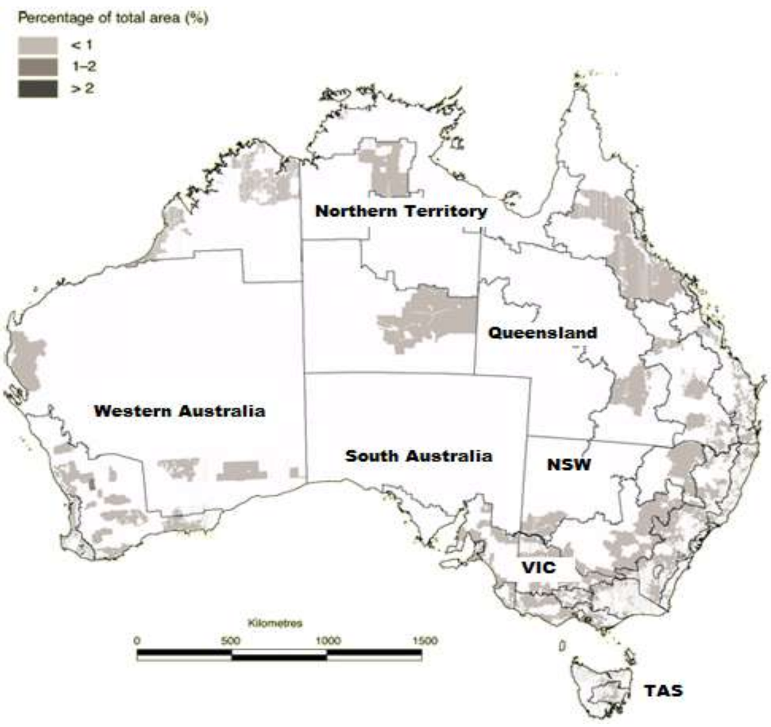
Potential for movement with commodities or conveyances

- Human-mediated movement of plants and plant products is considered the primary mode for the introduction of plant pathogens. Species of the genus *Phytophthora* are commonly spread in this way and have caused severe epidemics in silviculture, horticulture as well as natural systems all over the world. As visual symptoms may not be present, and in the absence of specific testing regimes, infected nursery stock could easily be moved into new areas. The introduction of infected plant material establishes the pathogen in new areas and unregulated movement will accelerate the spread of these pathogens.
- *Phytophthora ramorum* has the potential to spread from its point of introduction to new areas within Australia by natural means (short distance spread by wind, water or soil) and human

mediated activities (long distance spread via trade in nursery stock). Asymptomatic infections may remain undetected and therefore, trade in nursery stock will help spread *P. ramorum* in Australia.

- The Australian nursery and garden industry is represented in all states and territories of Australia (Map 5). This industry is spread over a wide area, with the greatest volume of production (82 percent) concentrated in the eastern states (New South Wales 35.7 percent, Queensland 28.4 percent and Victoria 17.9 percent) (IBIS World 2008). If infected host material is imported and distributed throughout these nurseries, this will help spread *P. ramorum* throughout Australia.

Map 5 Distribution of the nursery and garden industry in Australia



Source: Australian Natural Resources Atlas, Commonwealth of Australia (2001)

- Genotypes of *P. ramorum* have been spread via nursery stock trade from Europe to North America (Goss et al. 2011). In Canadian nurseries, the clonal lineages NA1, NA2 and EU1 have been found. NA2 is the most common lineage whereas NA1 is rare. In addition, the EU1 lineage is frequently detected in Canada (Goss et al. 2011), indicating that EU1 has spread from Europe to North America (Goss et al. 2011). Therefore, the pathogen has the ability to spread with nursery stock within Australia.
- The rapid spread of *P. ramorum* during the early 2000s, in Europe and in the USA, is related to the movement of infected nursery stock from infested regions into new areas (Brasier 2007; Cave et al. 2008; Alexander 2012); therefore, trade in nursery stock will help spread *P. ramorum* in Australia.
- The increased trade of plants within and between countries has led to new opportunities for plant pathogens to be moved to new areas or countries (Sansford et al. 2009; Dehnen-Schmutz et al. 2010; Webber 2010; Wingfield et al. 2010; Stenlid et al. 2011). In Europe, *P. ramorum* has spread to many countries, primarily on nursery plants of *Camellia japonica, Kalmia latifolia, Leucothoe* species, *Pieris formosa* var. *forrestii, P. japonica, Rhododendron*

species*, Syringa vulgaris, Taxus baccata* and *Viburnum* species (Werres & De Merlier 2003; Husson et al. 2007).

- *Phytophthora ramorum* can also spread by animal vectors; snails, shore fly larvae and fungus gnat larvae are known carriers of fungal propagules including chlamydospores and sporangia (Hyder et al. 2009).
- *Phytophthora* species are capable of surviving for several months in the soil. For example, *P. ramorum* can survive for at least eight to 11 months in soil or potting media (Shishkoff 2007). Chlamydospores germinate and form sporangia near roots and infected root tips can be seen covered with sporangia (Shishkoff 2007). *Phytophthora kernoviae* is not known to produce chlamydospores; the propagule most likely involved in soil infestation will be oospores (Widmer 2010). Therefore, the movement of contaminated soil, growing media or debris, particularly around nursery, garden and landscape developments, will help spread *Phytophthora* species in Australia.
- *Phytophthora ramorum* has also been detected in rivers and streams near outbreak sites. In California, *P. ramorum* has been recovered in streams at sites eight kilometres downstream of known infestations and at sites with no prior known forest infestations (Davidson et al. 2005; Murphy & Rizzo 2005; Murphy et al. 2006). Therefore, irrigation from infected sources could also spread the pathogen.
- Contaminated footwear is another potentially significant source of pathogen spread, particularly in areas of public access*. Phytophthora ramorum* has been detected seasonally from soil on hiking trails and from soil on hikers' boots (Davidson et al. 2002a; 2005; Tjosvold et al. 2002). Spores of *P. ramorum* have also been detected on the tyres of mountain bikes and vehicles used on dirt roads or trails in infested areas (Davidson & Shaw 2003). Subsequent movement to other natural areas by these visitors will help spread *P. ramorum* into new areas (Brasier et al. 2007).
- Numerous hosts of *P. ramorum* are popular for cut flower production, including *Acer, Camellia, Hamamelis, Kalmia, Pieris, Rhododendron* and *Syringa* species; therefore, *P. ramorum* could spread with trade in cut flowers and branches for decorations from infested areas within Australia.
- In the absence of statutory control there is a high probability that *Phytophthora* species will spread quickly in Australia through the trade of host plants for planting. Spread from nurseries into the environment will be facilitated by the planting of infected plants. Planting of infected propagative material will bring the *Phytophthora* species under review into the environment. Climatic conditions, such as those found in propagation houses, may be sufficient for its survival and spread.

Potential natural enemies

- *Phytophthora ramorum* is not known to have any natural enemies in Australia that could hamper its spread.

4.1.4 Overall likelihood of entry, establishment and spread

The overall likelihood of entry, establishment and spread is determined by combining the likelihoods of entry, establishment and spread using the matrix of 'rules' for combining qualitative likelihoods shown in Table 2.

- The likelihood that the *Phytophthora* species will enter Australia on host plant propagative material from countries where this pathogen is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia is **HIGH**.

4.1.5 Consequences

The potential consequences of the introduction and spread of the *Phytophthora* species in Australia have been estimated according to the methods described in Table 3. The introduction of these *Phytophthora* species will have unacceptable economic consequences in Australia as they will cause a variety of direct and indirect economic impacts. In assessing the potential impact of *Phytophthora* species in Australia, the economic losses caused by these pathogens in Europe and the USA were considered.

Reasoning for these ratings is provided below:

Criterion	Estimate and rationale
Direct	
Plant life or health	E – Significant at the regional level *Phytophthora ramorum* is one of the most destructive pathogens of oak and other host plants as it can destroy susceptible hosts within a short period of time (Rizzo et al. 2002b; Ivors et al. 2004). *Phytophthora ramorum* has the potential to cause economic consequences as it attacks hosts with significant commercial value and directly causes tree mortality. • *Phytophthora ramorum* is capable of killing healthy mature oak, tanoak, Japanese larch, wild *Rhododendron* species, evergreen huckleberries and *Viburnum* species. Thousands of *Lithocarpus* and *Quercus* species plants have been killed in California and Oregon, USA (Rizzo et al. 2005). Direct mortality has also been recorded in *Arbutus, Fagus, Rhododendron* and *Vaccinium* species. This pathogen also causes tip dieback on several hosts, and disfiguring leaf spots on several common nursery species, thereby rendering the plants unmarketable. • Many of the primary species in plantation and native forests, on which the Australian timber industry is based (*Eucalyptus* and *Pinus* species), are known hosts of *P. ramorum*. • The host range of *P. ramorum* includes many important species from Australia's horticultural industries, such as the blackberry (*Rubus* species), blueberry (*Viburnum* species), chestnut (*Castanea* species) and custard apple (*Annona* species) industries. For example, *Castanea sativa* is commercially grown for the production of sweet chestnuts and gourmet mushrooms. • Susceptible hosts include plants of importance to the nursery industry with amenity value in parks and gardens (*Acer, Quercus, Pieris, Prunus* and *Rosa* species). Some highly prized ornamentals are of key epidemiological importance for *P. ramorum* (*Camellia, Rhododendron* and *Viburnum* species). *Phytophthora ramorum* may also have adverse effects on the health of trees of historic importance in town streetscapes, cemeteries and churchyards (*Taxus* species). • The economic impact on plant life or health may depend on the extent of symptom

Criterion	Estimate and rationale
	expression on Australian species of commercial value. Evidence to date suggests that direct host mortality may be restricted to canker hosts in Fagaceae, and shoot dieback hosts in Ericaceae and Pinaceae. In hosts belonging to other families, twig and leaf infections are more common, enhancing the spread of the pathogen. This can result in yield reductions and enhanced susceptibility to other stresses.
Other aspects of the environment	F – Major significance at regional level Heavy loss of oaks, or related susceptible genera, could result in significant ecological effects, including changes in forest composition, loss of wildlife, reduced food and habitat availability, increased soil erosion and a significant increase in fuel loads in heavily populated urban-forest interfaces. • Loss of dominant trees and a reduction in cover may reduce the habitat for wildlife (Cave et al. 2005) and enhance weed invasion and erosion (CABI 2014). Such complex interactions are also likely in Australian sclerophyll communities, and will complicate the management of Australian ecosystems for the delivery of multiple services. • *Phytophthora ramorum* has a wide host range including eleven genera (*Adiantum, Cinnamomum, Dryopteris, Eucalyptus, Euonymus, Gaultheria, Ilex, Nothofagus, Pittosporum, Rhododendron* and *Rubus*) native to Australia. Some of these are major components of Australian ecosystems and production forests. Major native vegetation types present in suitable climate regions in which species susceptible to *P. ramorum* are dominant include Eucalypt tall open forests, Eucalypt open forests, Eucalypt low open forests, Eucalypt woodlands, Eucalypt open woodlands, Mallee woodlands and heath. Many of these vegetation types have been extensively cleared and are highly fragmented, which may make them more susceptible to invasion by *P. ramorum*. • There is a relationship between *P. ramorum* and fire in forests in regions of the USA with a Mediterranean climate. Foliar moisture contents of infected tanoak is lower (Kuljian & Varner 2010) and this lower moisture content increases the risk of canopy fires (Kuljian & Varner 2010). In addition to moisture decreases in the foliage, there is an increase in deadwood and fuels (Metz et al. 2010; 2011). It is likely that similar conclusions can be drawn for the effect on fire risk of a *P. ramorum* outbreak in other Mediterranean climates, where forests and shrublands are already particularly vulnerable to fires. • In the USA, *Phytophthora ramorum* has had major impacts on mixed evergreen forests and tanoak-redwood forests, where declines in highly susceptible species are resulting in changes in the composition of these communities. • The implications of *P. ramorum* on natural ecosystems, agriculture and horticulture may potentially be far worse than that currently posed by *P. cinnamomi* (O'Gara et al. 2005), which is an introduced pathogen with a wide host range that has caused immense damage to Australian forests.
Indirect	
Eradication, control, etc.	F – Major significance at the regional level The combination of human induced introductions (Mascheretti et al. 2009), potential human-mediated spread (Cushman & Meentemeyer 2008) and natural spread (Mascheretti et al. 2008; Davis et al. 2010) makes this a difficult pathogen to eradicate once introduced into the wild (Prospero et al. 2007). • Programs to minimise the impact of this pathogen in landscapes are likely to be costly and include the removal or pruning of affected and unaffected hosts, clear cutting, burning, disposal of infected plant material, herbicide treatment of cut stumps and broadcast burning to consume the litter layer (Goheen et al. 2006a). • Control measures may require treatments of green waste, stream water and prevention of soil movement (Rizzo et al. 2005). Appropriate disposal of *P. ramorum* infected green waste is considered a major economic issue for quarantined counties in California (Cave et al. 2005). The need for management, precautionary and sanitary practices, and

Criterion	Estimate and rationale
	regulations to prevent the further spread of the pathogen—such as washing of vehicles, closure of roads, and public education campaigns—in countries where the pathogen is established, has imposed a significant cost burden on industry and governments (CABI 2014). In addition, implementation of extensive disease surveillance and sampling programs may be required to ensure early detection and to contain further spread of the pathogen once it has established in the landscape, as in the USA (Goheen et al. 2006a). • Eradication will include cutting and burning all infected and nearby host plants, and where permissible, herbicide application to prevent sprouting of host plants.
Domestic trade	E – Significant at the regional level • The presence of *P. ramorum* is likely to result in domestic movement restrictions for host plants. Interstate restrictions on nursery stock may lead to a loss of markets, which would be likely to require industry adjustment. • Stringent controls on domestic trade would be required if *P. ramorum* became established in Australia. Restrictions might apply to domestic trade in nursery stock, forest products and other commodities.
International trade	E – Significant at the regional level • Because of the threat *P. ramorum* poses to oak-dominated forests throughout North America, many state governments have reacted strongly to the possible introduction of the pathogen via the nursery trade. • If *P. ramorum* established in Australia, restrictions on Australian exports of nursery stock would be anticipated. At least 68 countries, including South Korea, Canada, Mexico, Taiwan and New Zealand, have established quarantine policies and protocols against plant materials from areas known to have the pathogen (Sansford et al. 2009). Establishment of *P. ramorum* in Australia may therefore reduce access to international markets and result in additional requirements to achieve phytosanitary conformity that will impose a cost burden.
Environmental and non-commercial	E – Significant at the regional level • Death or dieback of host plants and restrictions on access to infested areas will impact negatively on the aesthetic, recreational and tourism value of town parks and natural recreation areas. Native Americans are concerned that the effect of *P. ramorum* on natural ecosystems may impact negatively on their traditional uses and values (Goheen et al. 2006a) which may also be true for indigenous Australians. • The control measures currently available are severe, and most (for example, host removal) are damaging to the urban and natural landscapes to which they are applied (Rizzo et al. 2005). Copper sulphate, copper hydroxide and mancozeb fungicides which may be used to control the pathogen (Cave et al. 2005) can have undesirable environmental consequences and exert selection pressures towards resistant isolates if applied at broad scales.

Based on the decision rules described in Table 4, that is, where the potential consequences of a pest with respect to more than one criteria have an impact of ‘F’, the overall consequences are estimated to be **EXTREME**.

4.1.6 Unrestricted risk estimate

Unrestricted risk is the result of combining the likelihoods of entry, establishment and spread with the outcome of overall consequences. Likelihood and consequences are combined using the risk estimation matrix shown in Table 5.

Unrestricted risk estimate for *Phytophthora ramorum*	
Overall likelihood of entry, establishment and spread	HIGH
Consequences	EXTREME
Unrestricted risk	EXTREME

As indicated, the unrestricted risk estimate for the *Phytophthora* species has been assessed as ‘extreme’, which is above Australia’s ALOP. Therefore, specific risk management measures are required for these *Phytophthora* species.

5 Pest risk management

Phytosanitary measures to prevent the introduction and spread of quarantine pests may include any combination of measures including pre- or post-harvest treatments, inspection at various points, surveillance, official control or certification. A measure or combination of measures may be applied at any one or more points along the continuum between the point of origin and the final destination. Pest risk management explores options that can be implemented (i) in the exporting country, (ii) at the point of entry or (iii) within the importing country. The ultimate goal is to prevent the introduction of identified quarantine pests in the PRA area.

Australia is a member of the World Trade Organisation (WTO) and has obligations under the Agreement on the Application of Sanitary and Phytosanitary Measures (WTO 1995). *Article 3* requires that members base their phytosanitary measures on international standards; however, it also allows members to use phytosanitary measures which result in a higher level of phytosanitary protection than that arising from international standards, where there is scientific justification or the member has determined that a higher level of protection is appropriate. *Article 5* requires that when determining the appropriate level of protection (ALOP), negative trade effects should be minimised. Phytosanitary measures were evaluated and selected to effectively restrict the risks posed to meet Australia's ALOP whilst minimising negative effects on trade.

The department considers that phytosanitary measures are justified against *Phytophthora* species under review as these pathogens pose an unrestricted risk exceeding Australia's ALOP.

5.1 Recommended risk mitigation measures

5.1.1 Propagative material from non-*Phytophthora ramorum* countries

This review recommends that the existing conditions for propagative material (tissue cultures, dormant cuttings, budwood and bare-rooted plants) from non-*Phytophthora ramorum* countries should continue. Additionally, it is recommended that the same conditions be extended to areas where *P. kernoviae, P. nemorosa* and *P. pseudosyringae* are not known to occur. The recommended conditions for *Phytophthora* species host propagative material (tissue cultures, dormant cuttings, budwood and bare-rooted plants) from non-*Phytophthora ramorum* countries are summarised below:

Tissue cultures (microplantlets)

- **Import permit:** An import permit is required;
- **Phytosanitary Certificate with an additional declaration:** Each consignment of tissue cultures must be accompanied with a Phytosanitary Certificate with an additional declaration stating '*Tissue cultures in this consignment were visually inspected immediately prior to export and found to be free from any symptoms of disease or microbial infection*';
- **Mandatory on-arrival inspection**: Each consignment must be subject to on-arrival inspection to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern. If tissue cultures have established roots or callus

development and they meet all on-arrival inspection requirements they may be released from quarantine; and

- **Mandatory growth in the PEQ:** If tissue cultures do not have established roots or callus development or do not meet on-arrival inspection requirements then they must be grown in approved PEQ facilities for disease screening prior to release.

Dormant hardwood cuttings, budwood and bare-rooted plants (other than tissue cultures)

- **Import permit:** An import permit is required;
- **Additional declaration on Phytosanitary Certification of country freedom:** Each consignment of dormant cuttings, budwood and bare-rooted plants must be accompanied with a Phytosanitary Certificate with an additional declaration stating '*Phytophthora kernoviae, Phytophthora nemorosa, Phytophthora pseudosyringae* and *Phytophthora ramorum* are not known to occur in [insert country of origin]';
- **Mandatory on-arrival inspection**: Each consignment of dormant cuttings, budwood and bare-rooted plants must be subject to on-arrival inspection to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern;
- **Mandatory on arrival treatment:** Each consignment of dormant cuttings, budwood and bare-rooted plants must be subject to on-arrival methyl-bromide fumigation. Methyl-bromide is a commonly used fumigant because of its effectiveness in killing arthropods regardless of the commodity. However, the department is recommending insecticidal dip as an alternative to methyl-bromide. The insecticidal dip (Imidacloprid 100 milligrams per litre and one percent Eco oil) is considered an appropriate broad spectrum insecticide, regardless of host. Methyl-bromide fumigation or insecticidal dip is not a treatment targeting the *Phytophthora* species under review; and
- **Mandatory growth in the PEQ:** Mandatory growth in PEQ of dormant hardwood cuttings, budwood and bare-rooted plants.

5.1.2 Propagative material from *Phytophthora ramorum* countries

This review recommends that *Phytophthora kernoviae, P. nemorosa* and *P. pseudosyringae* be treated as posing similar risk as *Phytophthora ramorum*. Therefore, propagative material from countries where *P. kernoviae, P. nemorosa* and *P. pseudosyringae* are known to occur should be subject to the same conditions.

The recommended risk management measures for *P. ramorum* host propagative material are based on a systems approach. Each of the recommended measures is not designed to be 'stand alone'; rather, the measures work in combination to ensure the risk is progressively reduced and managed. The department considers the recommended risk management measures reduce the risk of *P. ramorum, P. kernoviae, P. nemorosa* and *P. pseudosyringae* to at least a very low level, thereby meeting Australia's appropriate level of protection (ALOP).

The review recommends that:

- **Natural hosts** of the *Phytophthora* species under review be regulated at the genus level (the host list may be amended from time to time to reflect identification of new hosts and amendments will be notified on the department's import conditions database); and

- **Experimental hosts** of *Phytophthora ramorum* should not be regulated; therefore, existing regulations will be lifted for experimental hosts of *Phytophthora ramorum*.

Tissue cultures (microplantlets)

Current import requirements allow tissue cultures of all natural hosts of the *Phytophthora* species under review entry into Australia, this is recommended to continue. Imported tissue cultures are to be well rooted prior to arrival as this helps in their establishment out of agar into the growth media.

The recommended conditions for *Phytophthora* species host propagative material (tissue cultures) from countries where these *Phytophthora* species are known to occur are summarised below:

- **Mandatory on-arrival inspection:** Imported tissue cultures must be subjected to mandatory on-arrival inspection to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern; and
- **Mandatory growth in PEQ facilities:** The imported tissue cultures must be grown in a closed government PEQ facility for a minimum of 12 months with pathogen screening/testing. The minimum PEQ period may be longer if plants are a host of other quarantine pathogens.

  Imported tissue cultures must be grown in mist beds/fog for the first six weeks at 19 °C to 25 °C to favour symptom expression. During growth in PEQ, tissue cultures must be subjected to visual inspection and molecular testing (a generic *Phytophthora* PCR of leaf tissues for each plant to verify freedom from *Phytophthora* species).

Dormant cuttings and budwood

The review recommends that one-year-old dormant cuttings and budwood of all natural hosts of the *Phytophthora* species under review are allowed entry into Australia.

The recommended conditions for one-year-old dormant cuttings and budwood from countries where these *Phytophthora* species are known to occur are summarised below:

- **Phytosanitary Certificate with an additional declaration:** Each consignment must be accompanied by a Phytosanitary Certificate with an additional declaration stating ‘dormant cuttings and budwood in this consignment were inspected by the NPPO and found free of obvious disease symptoms’;
- **Mandatory on arrival inspection:** Imported one-year-old dormant cuttings and budwood must be subjected to mandatory on-arrival inspection to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern;
- **Mandatory on-arrival treatment:** Imported one-year-old dormant cuttings and budwood must be subjected to mandatory on-arrival methyl-bromide fumigation or insecticidal dip to address the risk of arthropod pests;
- **Mandatory culturing on-arrival:** Imported one-year-old dormant cuttings and budwood must be subjected to mandatory culturing to detect fungal pathogens including the *Phytophthora* species under review;

- **Mandatory molecular testing on-arrival:** Pre-screening of imported one-year-old dormant cuttings and budwood using a generic *Phytophthora* PCR. Stem tissues from imported dormant cuttings and budwood must be removed and subjected to a mandatory generic *Phytophthora* PCR;
- **Mandatory sodium hypochlorite treatment:** Imported one-year-old dormant cuttings and budwood must be subjected to a sodium hypochlorite treatment (NaOCl solution of one percent available chlorine for five minutes) for surface sterilisation; and
- **Mandatory growth in PEQ facilities:** Imported one-year-old dormant cuttings and budwood must be grown in a closed government PEQ facility for a minimum of 12 months; with pathogen screening and testing.

  Imported one-year-old dormant cuttings and budwood must be grown in mist beds/fog for the first six weeks at 19 °C to 25 °C to favour symptom expression.

  During growth in PEQ, imported one-year-old dormant cuttings and budwood must be subjected to visual inspection and molecular testing. It is recommended that a generic *Phytophthora* PCR of leaf tissues for each plant be carried out. If *Phytophthora* species are detected, then additional identification or molecular testing should be carried out.

Bare-rooted plants without foliage

The review recommends that one-year-old bare-rooted plants without foliage of all natural hosts of the *Phytophthora* species under review be allowed entry into Australia, subject to import conditions.

Bare-rooted plants should be imported during October to February from the Northern Hemisphere. If this does not occur, there may be delays in the release of planting material because the growth period may be too short to obtain sufficient material to conduct the required testing.

The recommended conditions for one-year-old bare-rooted plants from countries where these *Phytophthora* species are known to occur are summarised below:

- **Phytosanitary Certificate with an additional declaration:** Each consignment must be accompanied by a Phytosanitary Certificate with an additional declaration stating 'the bare-rooted plants have been inspected by the NPPO and found free of obvious disease symptoms';
- **Mandatory on arrival inspection:** Imported one-year-old bare-rooted plants must be subjected to mandatory on-arrival inspection to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern;
- **Mandatory on-arrival treatment:** Imported one-year-old bare-rooted plants must be subjected to mandatory on-arrival methyl-bromide fumigation or insecticidal dip to address the risk of arthropod pests;
- **Mandatory culturing on-arrival:** Imported one-year-old bare-rooted plants must be subjected to mandatory culturing to detect fungal pathogens including the *Phytophthora* species under review;

- **Mandatory molecular testing on-arrival:** Imported one-year-old bare-rooted plants must be subjected to a mandatory generic *Phytophthora* PCR on-arrival to pre-screen for the *Phytophthora* species under review;

- **Mandatory sodium hypochlorite treatment:** Imported one-year-old bare-rooted plants must be subjected to sodium hypochlorite treatment (NaOCl solution of one percent available chlorine for five minutes) for surface sterilisation; and

- **Mandatory growth in PEQ facilities:** Imported one-year-old bare-rooted plants must be grown in a closed government PEQ facility for a minimum of 15 months; with pathogen screening and testing.

  Imported one-year-old bare-rooted plants must be grown in mist beds/fog for the first six weeks at 19 °C to 25 °C to favour symptom expression.

  During growth in PEQ, imported propagative material must be subjected to visual inspection and molecular testing. It is recommended that a generic *Phytophthora* PCR of leaf tissues for each plant be carried out. If *Phytophthora* species are detected then additional identification or molecular testing should be carried out.

6 Conclusion

The findings of this final review of policy are based on a comprehensive analysis of the scientific literature. *Phytophthora kernoviae*, *P. nemorosa* and *P. pseudosyringae* share a similar host range and geographic range with *P. ramorum* and cause symptoms that are indistinguishable from those caused by *P. ramorum*. Therefore, these *Phytophthora* species are identified as pests of quarantine concern to Australia. Accordingly, the host list for *Phytophthora kernoviae*, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum* was revised. The review recommends that:

- natural hosts of *P. ramorum*, *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae* be regulated at genus level; and
- experimental hosts should be removed from the regulated host list.

The recommended risk management measures for *P. ramorum* host propagative material are based on a systems approach. Each of the recommended measures is not designed to be 'stand alone'; rather, the measures work in combination to ensure the risk is progressively reduced and managed. The department considers the recommended risk management measures reduce the risk of *P. ramorum, P. kernoviae, P. nemorosa* and *P. pseudosyringae* to at least a very low level, thereby meeting Australia's appropriate level of protection (ALOP). This review recommends the following tiered approach:

Off-shore measures to minimise risks

- Bare-rooted plants are produced in a commercial environment and inspected by the NPPO to verify freedom from disease symptoms.
- Restricting bare-rooted plants, budwood and dormant cuttings to one-year-old material, thereby lessening the exposure of material to disease infection.
- An official Phytosanitary Certificate endorsed with an additional declaration that bare-rooted plants, dormant cuttings, budwood and tissue cultures have been inspected and found free from obvious disease symptoms.

On-shore measures to minimise risks

- On-arrival examination of bare-rooted plants, budwood and dormant cuttings for disease symptoms, treatment (surface sterilization, fumigation) and growth under conditions that favour symptom expression (mist and air temperatures of 19 °C to 25 °C for six weeks).
- On-arrival examination of tissue cultures to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern.

On-arrival testing

- On-arrival, propagative material (bare-rooted plants, budwood and dormant cuttings) is cultured on selective culture media and tested for *Phytophthora* species using a generic PCR.

Minimum 12 to 15 month growth in Post Entry Quarantine (PEQ)

- Mandatory growth of propagative material in a closed government PEQ facility for a minimum of 12 to 15 months (dormant cuttings, budwood and tissue cultures for a minimum of 12 months, bare-rooted plants for a minimum of 15 months) with disease screening.

- Imported one-year-old bare-rooted plants, dormant cuttings and budwood must be grown in mist beds/fog for the first six weeks at 19 °C to 25 °C to favour symptom expression.
- During growth in PEQ, imported one-year-old bare-rooted plants, dormant cuttings, budwood and tissue cultures must be subjected to visual inspection and molecular testing. It is recommended that a generic *Phytophthora* PCR of leaf tissues for each plant be carried out. If *Phytophthora* species are detected then additional identification or molecular testing should be carried out.

The existing conditions for propagative material from countries where these *Phytophthora* species are not known to occur are recommended to continue.

Appendix A: Natural hosts of *Phytophthora* species and their status in Australia

The host ranges of *Phytophthora ramorum, P. kernoviae*, *P. nemorosa* and *P. pseudosyringae* overlap; therefore, some of the hosts listed may also be susceptible to these other *Phytophthora* species. Unless specified, the hosts listed in the table are *P. ramorum* hosts, where species are known to be susceptible to *P. kernoviae*, *P. nemorosa* or *P. pseudosyringae,* this is indicated in the table. The synonyms listed in this table are based on the Missouri Botanical Garden taxonomic database, Tropicos (tropicos.org). The geographical distribution in Australia of the natural hosts of the *Phytophthora* species under review is provided (source: Australia's Virtual Herbarium 2014, unless otherwise specified). While the hosts of these *Phytophthora* species are regulated at the genus level, this table has been completed at the species level and all subordinate taxa are subject to the same conditions as the species. Hybrids are not listed in this table unless one of the parent species does not belong to a genus that is not known to be a natural host of the *Phytophthora* species under review.

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Abies concolor (Gordon & Glend.) Lindl. ex Hildebr. [Pinaceae] – White fir	*Abies lowiana* (Gordon) A. Murray bis, *Picea concolor* Gordon & Glend., *Picea lowiana* Gordon, *Pinus concolor* Engelm. ex Parl., *Pinus lowiana* (Gordon) Mc Nab	Cave et al. 2008; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Abies grandis (Douglas ex D. Don) Lindl. [Pinaceae] – Grand fir	*Pinus grandis* Douglas ex D. Don	Cave et al. 2008; Riley et al. 2011	VIC
Abies magnifica A. Murray [Pinaceae] – California red fir	-	Cave et al. 2008; Chastagner & Riley 2010	Recorded in Australia, but location not specified (Randall 2007)
Abies procera Rehder [Pinaceae] – Noble fir	*Abies nobilis* (Douglas ex D. Don) Lindl.	FERA 2012	TAS
Acer circinatum Pursh [Aceraceae] – Vine maple	-	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Acer davidii Franch. [Aceraceae] – Striped bark maple	-	Cave et al. 2008	VIC
Acer laevigatum Wall. [Aceraceae] – Evergreen maple	-	Cave et al. 2008	Recorded in Australia, but location not specified (Randall 2007)
Acer macrophyllum Pursh [Aceraceae] – Bigleaf maple	-	Scianna et al. 2003	Recorded in Australia, but location not specified (Randall 2007)
Acer pseudoplatanus L. [Aceraceae] – Sycamore maple	-	Cave et al. 2008	SA, NSW, VIC, TAS

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Adiantum jordanii Mueller [Pteridaceae] – California maiden hair	-	Vettraino et al. 2006a	Not listed as occurring in Australia
Adiantum pedatum L. [Pteridaceae] – Northern Maidenhair Fern, Five-finger Fern	*Adiantum aleuticum* (Rupr.) C.A. Paris, *Adiantum boreale* C. Presl, *Adiantum hispidulum* Sw.*	Vettraino et al. 2006a	Recorded in Australia, but location not specified (Randall 2007)
Aesculus californica (Spach) Nutt. [Hippocastanaceae] – California buckeye	-	Garbelotto et al. 2003; Scianna et al. 2003	Recorded in Australia, but location not specified (Randall 2007)
Aesculus hippocastanum L. [Hippocastanaceae] – Horse chestnut	*Hippocastanum vulgare* Gaertn.	Cave et al. 2008; Sansford et al. 2009	SA, NSW, ACT
Alnus glutinosa (L.) Gaertn. [Betulaceae] (L.) Lam.) – European alder (Only reported as a host of *Phytophthora pseudosyringae*)	*Alnus alnus* (L.) Britton, *Alnus vulgaris* Hill	Jung et al. 2003	SA, NSW, ACT, TAS
Annona cherimola Mill. [Annonaceae] – Cherimoya, Custard apple (Only reported as a host of *Phytophthora kernoviae*)	*Annona pubescens* Salisb., *Annona tripetala* Aiton	Ramsfield et al. 2009; EPPO 2013	Recorded in Australia, but location not specified (Randall 2007)
Arbutus menziesii Pursh [Aracaceae] – Madrone	-	Maloney et al. 2002	Recorded in Australia, but location not specified (Randall 2007)
Arbutus unedo L. [Aracaceae] – Strawberry tree	-	Sansford et al. 2009	ACT, SA, NSW, VIC, TAS, WA
Arctostaphylos columbiana Piper [Ericaceae] – Hairy manzanita	-	Sansford et al. 2009; Hansen et al. 2003a	Recorded in Australia, but location not specified (Randall 2007)
Arctostaphylos glandulosa Eastw. [Ericaceae] – Eastwood manzanita	-	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Arctostaphylos manzanita Parry [Ericaceae] – Whiteleaf	-	Garbelotto et al. 2003; Scianna et al. 2003; Cave et al. 2008	ACT
Arctostaphylos uva-ursi (L.) Spreng. [Ericaceae] – Kinnikinnick	*Arbutus buxifolia* Stokes, *Arbutus uva-ursi* L., *Arctostaphylos adenotricha* (Fernald & J.F. Macbr.) Á. Löve, D. Löve & B.M. Kapoor, *Arctostaphylos coloradensis* Rollins, *Arctostaphylos officinalis* Wimm. & Grab., *Arctostaphylos procumbens* E. Mey., *Daphnidostaphylis fendleri* Klotzsch,	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
	Mairania uva-ursi (L.) Desv., *Uva-ursi buxifolia* (Stokes) Gray, *Uva-ursi procumbens* Moench, *Uva-ursi uva-ursi* (L.) Britton, *Uva-ursi uva-ursi* (L.) Cockerell		
Arctostaphylos virgata Eastw. [Ericaceae] – Bolinas manzanita, Marin manzanita	-	COMTF 2015	Not listed as occurring in Australia
Ardisia japonica (Thunb.) Blume [Myrsinaceae] – Marlberry, Ardisia	*Bladhia japonica* Thunb., *Tinus japonica* (Thunb.) Kuntze	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Artemisia tridentata Nutt. [Asteraceae] – Big Sagebush	*Seriphidium tridentatum* (Nutt.) W.A. Weber	Vettraino et al. 2010	Not listed as occurring in Australia
Berberis aquifolium Pursh [Berberidaceae] – Holly leaved barberry, Oregon grape	*Berberis dictyota* Jeps.*, *Mahonia aquifolium* (Pursh) Nutt.	COMTF 2015	ACT, NSW, SA, TAS, VIC
Berberis nervosa Pursh [Berberidaceae] – Cascades mahonia, Creeping Oregon grape	*Mahonia nervosa* (Pursh) Nutt.	COMTF 2015	Not listed as occurring in Australia
Betula pendula Roth [Betulaceae] – European white birch	*Betula platyphylloides* V.N. Vassil., *Betula pseudopendula* V.N. Vassil., *Betula talassica* Poljakov, *Betula verrucosa* Ehrh.	COMTF 2015	TAS, ACT, VIC, NSW, SA
Calluna vulgaris (L.) Hull [Ericaceae] – Heather	-	Cave et al. 2008; Sansford et al. 2009; Orlikowski & Szkuta 2004	TAS, ACT, NSW, QLD
Calycanthus occidentalis Hook. & Arn. [Calycanthaceae] – Western sweetshrub	*Butneria occidentalis* (Hook. & Arn.) Greene	COMTF 2015	ACT, NSW, VIC
Camellia L. species [Theacae] – Camellia (all species, hybrids and cultivars)	*Bembiciopsis* H. Perrier, *Thea* L.	Pintos Varela et al. 2003; Beales et al. 2004a	QLD, VIC, ACT, NSW, SA
Camellia japonica L. [Theacae] – Camellia	*Thea japonica* (L.) Baill.	Pintos Varela et al. 2003	ACT, VIC, NSW, SA
Camellia reticulata Lindl. [Theacae] – Camellia	*Camellia albescens* H.T. Chang, *Camellia albosericea* H.T. Chang, *Camellia albovillosa* H.H. Hu ex H.T. Chang, *Camellia bailinshanica* H.T. Chang, H.S. Liu & G.X. Xiang, *Camellia bambusifolia* H.T. Chang, H.S. Liu & Y.Z. Zhang, *Camellia borealiyunnanica* H.T. Chang, *Camellia brevicolumna* H.T. Chang, H.S. Liu &	Parke et al. 2004b	Recorded in Australia, but location not specified (Randall 2007)

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
	Y.Z. Zhang, *Camellia brevigyna* H.T. Chang, *Camellia brevipetiolata* H.T. Chang, *Camellia chunii* (H.T. Chang) H.T. Chang, *Camellia heterophylla* H.H. Hu, *Camellia jinshajiangica* H.T. Chang, *Camellia kangdianica* H.T. Chang, H.S. Liu & G.X. Xiang, *Camellia kweichowensis* H.T. Chang, *Camellia oligophlebia* H.T. Chang, *Camellia paucipetala* H.T. Chang, *Camellia pentapetala* H.T. Chang, *Camellia pentaphylacoides* H.T. Chang, *Camellia pentaphylax* H.T. Chang, *Camellia stichoclada* H.T. Chang, *Camellia subliberopetala* H.T. Chang, *Camellia xichangensis* H.T. Chang, *Camellia xylocarpa* (H.H. Hu) H.T. Chang, *Desmitus reticulata* (Lindl.) Raf., *Thea reticulata* (Lindl.) Pierre, *Yunnanea xylocarpa* H.H. Hu		
Camellia sasanqua Thunb. [Theacae] – Camellia	-	Parke et al. 2004b	ACT, NSW
Camellia sinensis (L.) Kuntze [Theacae] – tea-plant	*Camellia thea* Link, *Thea assamica* J.W. Mast., *Thea sinensis* L.	Blomquist et al. 2015	QLD
Carpinus betulus [Betulaceae] – Hornbeam (Only reported as a host of *Phytophthora pseudosyringae*)	-	Goheen & Frankel 2009; Denman et al. 2007	SA
Castanea sativa Mill. [Fagaceae] – European chestnut, Sweet chestnut	*Castanea vesca* Gaertn, *Castanea vulgaris* Lam., *Fagus castanea* L.	Sansford et al. 2009; COMTF 2015	ACT, NSW, VIC, SA
Castanopsis orthacantha Franchet [Fagaceae]	*Castanopsis concolor* Rehder & E.H. Wilson, *Castanopsis mianningensis* H.H. Hu, *Castanopsis tenuinervis* A. Camus, *Castanopsis yanshanensis* H.H. Hu	Sansford et al. 2009	Not listed as occurring in Australia
Ceanothus thyrsiflorus Eschsch. [Rhamnaceae] – Blue blossom, Californian lilac	-	Cave et al. 2008; COMTF 2015	SA, ACT, NSW
Cercis chinensis Bunge [Fabaceae] – Chinese	*Cercis pauciflora* H.L. Li	Sansford et al. 2009	Recorded in Australia, but location not

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
redbud			specified (Randall 2007)
Chamaecyparis lawsoniana (A. Murray) Parl. [Cupressaceae] – Lawson's cypress	*Cupressus lawsoniana* A. Murray	COMTF 2015; Brasier & Webber 2012	NSW, ACT, SA, TAS
Choisya ternata Kunth [Rutaceae] – Mexican-orange	-	COMTF 2015	ACT, SA, NSW, VIC
Chrysolepis chrysophylla (Dougl. ex Hook.) Hjelmqvist [Fagaceae] – Chinquapin, Golden chinquapin (Listed as *Chrysolepsis chrysophylla*, which is not an accepted name)	*Castanea chrysophylla* Douglas ex Hook., *Castanopsis chrysophylla* (Douglas ex Hook.) A. DC.	COMTF 2015	Not listed as occurring in Australia
Cinnamomum camphora (L.) J. Presl [Lauraceae] – Camphor laurel	*Camphora officinarum* Nees, *Cinnamomum camphoroides* Hayata, *Cinnamomum nominale* (Hayata) Hayata, *Cinnamomum simondii* Lecomte, *Cinnamomum taquetii* H. Lév., *Laurus camphora* L., *Persea camphora* (L.) Spreng.	COMTF 2015; Sansford et al. 2009; Rooney-Latham et al. 2013	QLD, NSW, WA, VIC, ACT, SA
Clintonia andrewsiana Torr. [Liliaceae] – Andrew's clintonia bead lily	-	Cave et al. 2008; COMTF 2015	Not listed as occurring in Australia
Cornus L. species [Cornaceae] – Cornel, Dogwood	*Arctocrania* (Endl.) Nakai, *Benthamia* Lindl., *Benthamidia* Spach, *Chamaepericlymenum* Hill, *Cornella* Rydb., *Cynoxylon* (Raf.) Small, *Eukrania* Raf., *Macrocarpium* (Spach) Nakai, *Ossea* Nieuwl. & Lunell, *Svida* Opiz, *Thelycrania* (Dumort.) Fourr.	RAPRA 2012	VIC, ACT, NSW, TAS
Cornus capitata Wall. [Cornaceae] – Bentham's dogwood, Bentham's cornel	*Benthamia capitata* (Wall.) Nakai, *Benthamia fragifera* Lindl., *Benthamidia capitata* (Wall.) H. Hara, *Cynoxylon capitatum* (Wall.) Nakai, *Cynoxylon glabriusculum* Pojark., *Cynoxylon yunnanense* Pojark., *Dendrobenthamia capitata* (Wall.) Hutch., *Dendrobenthamia emeiensis* W.P. Fang & Y.T. Hsieh	Sansford et al. 2009; RAPRA 2012	VIC, NSW, ACT, TAS
Cornus kousa Hance [Cornaceae] – Chinese dogwood, Japanese dogwood	-	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Cornus nuttallii Audubon [Cornaceae] - Mountain dogwood, Pacific dogwood, Western dogwood	-	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Corylopsis spicata Siebold & Zucc. [Hamamelidaceae] – Spike winter hazel	-	COMTF 2015	ACT, VIC
Corylus cornuta Marshall [Betulaceae] – California hazelnut	*Corylus rostrata* Aiton	Cave et al. 2008; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Cotoneaster Medik. species [Rosaceae] (*Cotoneaster horizontalis* and *C. dammeri* are reported as experimental hosts only (Bulajić et al. 2010))	-	FERA 2012	NSW, SA, ACT, VIC, TAS, QLD, WA
Cryptantha torreyana (A. Gray) Greene [Boraginaceae] – Torrey's cryptantha	-	Vettraino et al. 2010	Not listed as occurring in Australia
Cydonia oblonga Mill. [Rosaceae] – Quince	*Cydonia vulgaris* Pers., *Pyrus cydonia* L.	RAPRA 2012	
Cytisus scoparius (L.) Link [Fabaceae] – Common broome, Scotch broome	*Sarothamnus scoparius* (L.) W. D. J. Koch, *Spartium scoparium* L.	Vettraino et al. 2010	NSW, ACT, VIC, SA, TAS
Daphniphyllum glaucescens Blume [Daphniphyllaceae]	-	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Distylium myricoides Hemsl. [Hamamelidaceae] – Myrtle-leafed distylium	-	Cave et al. 2008	Recorded in Australia, but location not specified (Randall 2007)
Drimys winteri J. R. Forst. & G. Forst. [Winteraceae] – Winter's bark	*Drimys chilensis* DC., *Drimys granatensis* Mutis ex L. f., *Drimys punctata* Lam.	COMTF 2015	VIC
Dryopteris arguta (Kaulf.) Maxon [Dryopteridiaceae] – Californian wood fern, Coastal woodfern	*Aspidium argutum* Kaulf.	COMTF 2015	Not listed as occurring in Australia
Eucalyptus haemastoma Sm. [Myrtaceae] – Scribbly gum	-	Sansford et al. 2009	NSW, ACT, VIC
Euonymus kiautschovicus Loes [Celastraceae] – Spreading euonymus, Creeping strawberry bush	*Euonymus fortunei* (Turcz.) Hand.-Mazz.*, *Euonymus hederaceus* Champ. ex Benth.*	Cave et al. 2008	Not listed as occurring in Australia
Fagus sylvatica L. [Fagaceae] – Beech	-	Sansford et al 2009; FERA 2012	NSW, SA, ACT, TAS, VIC

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Frangula californica (Eschsch.) A. Gray [Rhamnaceae] – Californian coffeeberry, California buckthorn	-	Goheen et al. 2006a; Garbelotto et al. 2003; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Frangula purshiana (DC.) J. G. Cooper [Rhamnaceae] – Cascara	-	Kliejunas 2003; Vettraino et al. 2006b; Vettraino et al. 2010	Recorded in Australia, but location not specified (Randall 2007)
Fraxinus excelsior L. [Oleaceae] – Ash	*Fraxinus apetala* Lam., *Fraxinus angustifolia* Vahl*, *Fraxinus hookeri* Wenz.*	Cave et al. 2008; Sansford et al. 2009; COMTF 2015	ACT, VIC, TAS, NSW, QLD
Fraxinus latifolia Benth. [Oleaceae] – Oregon ash	*Fraxinus oregona* Nutt.	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Garrya elliptica Douglas ex Lindl. [Garryaceae] – Silk tassel bush	-	Sansford et al. 2009	ACT, SA, NSW, TAS
Gaultheria procumbens L. [Ericaceae] – Wintergreen, Checkerberry	-	COMTF 2015; FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
Gaultheria shallon Pursh [Ericaceae] – Salal, Oregon wintergreen	-	Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Gevuina avellana Molina [Proteaceae] – Chilean wildnut, Avellana (Only reported as a host of *Phytophthora kernoviae*)	*Quadria avellana* (Molina) C.F. Gaertn., *Quadria heterophylla* Ruiz & Pav.	Hughes et al. 2005	NSW
Griselinia littoralis (Raoul) Raoul [Cornaceae]– New Zealand privet	-	Giltrap et al. 2007; COMTF 2015	TAS, NSW, VIC
Hamamelis mollis Oliv.[Hamamelidaceae] – Chinese witch hazel	-	COMTF 2015	ACT
Hamamelis virginiana L. [Hamamelidaceae]– Virginian witch hazel	*Hamamelis androgyna* Walter, *Hamamelis corylifolia* Moench, *Hamamelis dioica* Walter, *Hamamelis macrophylla* Pursh, *Trilopus dentata* Raf., *Trilopus estivalis* Raf., *Trilopus nigra* Raf., *Trilopus parvifolia* (Nutt.) Raf., *Trilopus rotundifolia* Raf., *Trilopus virginica* (L.) Raf.	Giltrap et al. 2004	VIC
Heteromeles arbutifolia (Lindl.) M. Roem. [Rosaceae]– California holly, Toyon,	*Heteromeles salicifolia* (C. Presl) Abrams*	Garbelotto et al. 2003; Kliejunas 2003	SA

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Christmasberry			
Hydrangea seemannii L. Riley [Hydrangeaceae] – Hydrangea	*Hydrangea oerstedii* Briq.*	FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
Ilex aquifolium L [Aquifoliaceae] – European holly	-	COMTF 2015	SA, NSW, TAS, VIC, ACT
Ilex cornuta Lindl. & Paxton [Aquifoliaceae] – Buford holly, Horned holly	*Ilex burfordii* S. R. Howell, *Ilex fortunei* Lindl., *Ilex furcata* Lindl. ex Göpp.	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Ilex latifolia Thunb. [Aquifoliaceae]– Tarajo holly	*Ilex tarajo* Göpp.	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Ilex purpurea Hassk [Aquifoliaceae] – Oriental holly	*Ilex chinensis* Sims*	FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
Illicium parviflorum Michx. ex Vent. [Schisandraceae] – Swamp star anise, Yellow anise	*Badianifera parviflora* (Michx. ex Vent.) Kuntze	COMTF 2015	NSW
Kalmia L. species [Ericaceae] – Laurel	*Chamaedaphne* Catesby ex Kuntze, *Kalmiella* Small	FERA 2012	ACT, SA
Kalmia angustifolia L. [Ericaceae] – Sheep laurel	-	Sansford et al. 2009	ACT
Kalmia latifolia L. [Ericaceae]– Mountain laurel	-	Sansford et al. 2009	SA
Larix decidua Mill. [Pinaceae]– European larch	*Larix europaea* Lam. & A. DC.	COMTF 2015; EPPO 2011; FERA 2012	TAS
Larix kaempferi (Lamb.) Carrière [Pinaceae] – Japanese larch, Larch	*Larix leptolepis* (Siebold & Zucc.) Gordon, *Pinus kaempferi* Lamb.	Webber et al. 2010a, b; FERA 2012	ACT, NSW
Laurus nobilis L. [Lauraceae] – Bay laurel	-	COMTF 2015	VIC, SA, ACT, TAS, NSW
Leucothoe axillaris (Lam.) D. Don [Ericaceae] – Fetter-bush, Dog hobble	-	Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Leucothoe fontanesiana (Steud.) Sleumer [Ericaceae] – Drooping leucothoe	-	Sansford et al. 2009	NSW, VIC
Liriodendron tulipifera L. [Magnoliaceae] –Tulip tree	*Liriodendron procera* Salisb., *Liriodendron truncatifolium* Stokes, *Tulipifera liriodendron*	Hughes et al. 2005	ACT, SA, NSW, TAS

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
	Mill.		
Lithocarpus densiflorus (Hook. & Arn.) Rehder [Fagaceae] – Tanbark oak	-	Blomquist et al. 2015	Recorded in Australia, but location not specified (Randall 2007)
Lithocarpus glaber (Thunb.) Nakai [Fagaceae] – Japanese oak	*Kuromatea glabra* (Thunb.) Kudô, *Lithocarpus thalassicus* (Hance) Rehder, *Pasania glabra* (Thunb.) Oerst., *Pasania sieboldiana* (Blume) Nakai, *Pasania thalassica* (Hance) Oerst., *Quercus glabra* Thunb., *Quercus sieboldiana* Blume, *Quercus thalassica* Hance, *Synaedrys glabra* (Thunb.) Koidz., *Synaedrys thalassica* (Hance) Koidz.	COMTF 2015	VIC
Lonicera hispidula (Lindl.) Douglas ex Torr. & A. Gray [Caprifoliaceae] – Californian honeysuckle	-	Garbelotto et al. 2003; Goheen et al. 2006a; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Lonicera periclymenum L. [Caprifoliaceae] – Honeysuckle, Woodbine	-	Sansford et al. 2009	QLD, NSW, TAS
Loropetalum chinense (R. Br.) Oliv. [Hamamelidaceae] – Loropetalum	-	Blomquist et al. 2012	ACT, NSW, VIC
Magnolia acuminata (L.) L. [Magnoliaceae] – Blue magnolia, Cucumber-tree, Yellow cucumber-tree	*Kobus acuminata* (L.) Nieuwl., *Magnolia acuminata* Hardin, *Magnolia cordata* Michx., *Tulipastrum acuminatum* (L.) Small, *Tulipastrum americanum* Spach, *Tulipastrum cordatum* (Michx.) Small	FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
Magnolia cavaleriei (Finet & Gagnep.) Figlar [Magnoliaceae] (Listed as *Magnolia cavalieri,* which is not an accepted name)	*Michelia cavaleriei* var. *cavaleriei**	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Magnolia delavayi Franch [Magnoliaceae] – Chinese Magnolia	*Lirianthe delavayi* (Franch.) N.H. Xia & C.Y. Wu*	FERA 2012	VIC
Magnolia denudata Desr. [Magnoliaceae] – Lily Tree	*Magnolia conspicua* Salisb., *Magnolia yulan* Desf., *Yulania denudata* (Desr.) D.L. Fu*	Sansford et al. 2009	VIC
Magnolia doltsopa (Buch.-Ham. ex DC.) Figlar [Magnoliaceae]– Michelia	-	Sansford et al. 2009; COMTF 2015	Not listed as occurring in Australia

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Magnolia ernestii Figlar [Magnoliaceae] – Michelia	*Michelia wilsonii* subsp. *wilsonii**	Sansford et al. 2009	Not listed as occurring in Australia
Magnolia figo (Lour.) DC. [Magnoliaceae] – Banana magnolia, Banana shrub	*Michelia figo* (Lour.) Spreng*	APHIS 2008a	Not listed as occurring in Australia
Magnolia foveolata (Merr. ex Dandy) Figlar [Magnoliaceae]	-	Sansford et al. 2009; COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Magnolia grandiflora L. [Magnoliaceae] – Magnolia	*Magnolia ferruginea* Z. Collins ex Raf., *Magnolia foetida* (L.) Sarg., *Magnolia lacunosa* Raf.	Sansford et al. 2009	NSW, QLD, SA, VIC
Magnolia kobus DC. [Magnoliaceae] – Kobus magnolia	*Buergeria obovata* Siebold & Zucc., *Magnolia praecocissima* Koidz., *Yulania kobus* (DC.) Spach	Sansford et al. 2009	NSW
Magnolia liliiflora Desr. [Magnoliaceae] – Purple magnolia	-	APHIS 2008b; COMTF 2015	VIC
Magnolia salicifolia (Siebold & Zucc.) Maxim. [Magnoliaceae] – Anise magnolia	-	Sansford et al. 2009	VIC
Magnolia stellata (Siebold & Zucc.) Maxim. [Magnoliaceae] – Star magnolia	-	Giltrap et al. 2007; Sansford et al. 2009	NSW
Maianthemum racemosum (L) Link [Liliaceae] – False Solomon's seal	*Convallaria racemosa* L., *Smilacina racemosa* (L.) Desf, *Unifolium racemosum* (L.) Britton	Hüberli et al. 2005; Vettraino et al. 2010	Recorded in Australia, but location not specified (Randall 2007)
Malus pumila Mill [Rosaceae]– Paradise apple (Only reported as a host of *Phytophthora pseudosyringae*)	*Malus domestica* Borkh.*, *Malus communis* Poir., *Malus dasyphylla* Borkh., *Malus niedzwetzkyana* Dieck ex Koehne, *Pyrus malus* L.	Sansford 2012	SA, VIC, NSW, QLD, ACT, TAS, WA
Manglietia insignis (Wall.) Blume [Magnoliaceae] – Red lotus tree	*Magnolia insignis* Wall., *Magnolia shangpaensis* H.H. Hu, *Manglietia maguanica* H.T. Chang & B.L. Chen, *Manglietia rufisyncarpa* Y.W. Law, R.Z. Zhou & F.G. Wang, *Manglietia yunnanensis* H.H. Hu	Cave et al. 2008; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Marah fabaceus (Naud.) Naud. ex Greene [Cucurbitaceae] – California manroot, Wild	-	Vettraino et al. 2010	Not listed as occurring in Australia

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
cucumber			
Michelia maudiae Dunn [Magnoliaceae] – Michelia	*Michelia chingii* W.C. Cheng	Sansford et al. 2009	VIC
Molinadendron sinaloense (Standl. & Gentry) P.K. Endress [Hamamelidaceae]	*Distylium sinaloense* Standl. & Gentry	COMTF 2015	Not listed as occurring in Australia
Myristica fragrans Houtt. [Myristicaceae] – Nutmeg	*Myristica aromatica* Lam., *Myristica moschata* Thunb., *Myristica officinalis* L., *Myristica officinalis* Mart.	Mathew & Beena 2012	Recorded in Australia, but location not specified (Randall 2007)
Nerium oleander L. [Apocynaceae] – Oleander	*Nerium indicum* Mill., *Nerium odoratum* Lam., *Nerium odorum* Sol., *Nerium verecundum* Salisb.	COMTF 2015	WA, SA, QLD, NSW, ACT, VIC, TAS
Nothofagus alpina (Poepp. & Endl.) Oerst. [Fagaceae] – Rauli beech	*Fagus alpina* Poepp. & Endl., *Fagus nervosa* Phil., *Fagus procera* Poepp. & Endl., *Nothofagus nervosa* (Phil.) Krasser, *Nothofagus procera* (Poepp. & Endl.) Oerst.	Scanu et al. 2012	Recorded in Australia, but location not specified (Randall 2007)
Nothofagus obliqua (Mirb.) Blume [Fagaceae] – Roble beech	*Nothofagus obliqua* subsp. *andina* F.M. Vázquez & R.A. Rodr.*, *Fagus obliqua* Mirb., *Nothofagus obliqua* (Mirb.) Blume.	Sansford et al. 2009	VIC
Notholithocarpus densiflorus (Hook. & Arn.) Manos et al. [Fagaceae]– Tanoak	-	Garbelotto et al. 2003; Hansen et al. 2003a; Scianna et al. 2003; Sansford et al. 2009; Vettraino et al. 2010	Recorded in Australia, but location not specified (Randall 2007)
Olea europaea L. [Oleaceae] – Olive (Listed as *Olea europa*, which is not an accepted name)	-	Blomquist et al. 2015	NSW, VIC, QLD, SA, WA, ACT, TAS
Osmanthus decorus (Boiss. & Balansa) Kasapligil [Oleaceae]– Osmanthus	*Phillyrea decora* Boiss. & Balansa, *Phillyrea medwedewii* Sred.	Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Osmanthus delavayi Franch. [Oleaceae] – Delavay osmanthus	*Ligustrum phillyrea* H. Lev., *Siphonosmanthus delavayi* (Franch.) Stapf.	Cave et al. 2008; RAPRA 2012; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Osmanthus fragrans Lour. [Oleaceae] – Sweet olive	*Olea fragrans* Thunb., *Olea ovalis* Miq., *Osmanthus longibracteatus* H.T. Chang, *Osmanthus macrocarpus* P.Y. Bai	Cave et al. 2008; Grünwald et al. 2008a; Sansford et al. 2009	NSW

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Osmanthus heterophyllus (G. Don) P. S. Green [Oleaceae] – Holly osmanthus, Holly olive	-	Grünwald et al. 2008a; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Osmorhiza berteroi DC. [Apiaceae] – Sweet cicely	*Osmorhiza chilensis* Hook. & Arn.*	Sansford et al. 2009	Not listed as occurring in Australia
Parakmeria lotungensis (Chun & C. H. Tsoong) Y. W. Law [Magnoliaceae] – Eastern joy lotus tree	*Magnolia lotungensis* Chun & C. H. Tsoong	Sansford et al. 2009	Not listed as occurring in Australia
Parrotia persica (DC.) C. A. Mey. [Hamamelidaceae] – Persian Ironwood	-	Hughes et al. 2006; Sansford et al. 2009	ACT, NSW, VIC
Photinia x *fraseri* Dress [Rosaceae] – Fraser's Photinia, Christmas berry	-	Sansford et al 2009; Orlikowski & Szkuta 2004	Recorded in Australia, but location not specified (Randall 2007)
Phoradendron serotinum subsp. *macrophyllum* (Engelm.) Kuijt [Santalaceae] – Mistletoe	-	Riley & Chastagner 2011	Not listed as occurring in Australia
Physocarpus opulifolius (L.) Maxim. [Rosaceae] – Ninebark	-	COMTF 2015	ACT, NSW
Picea sitchensis (Bong.) Carrière [Pinaceae] – Sitka spruce	*Abies falcata* Raf., *Abies menziesii* (Douglas ex D. Don) Lindl., *Picea falcata* (Raf.) Suringar, *Picea menziesii* (Douglas ex D. Don) Carrière, *Pinus menziesii* Douglas ex D. Don, *Pinus sitchensis* Bong.	COMTF 2015; FERA 2012	NSW, SA
Pickeringia montana Nutt. [Fabaceae] – Chaparral pea	*Xylothermia montana* (Nutt.) Greene	COMTF 2015	Not listed as occurring in Australia
Pieris floribunda (Pursh) Benth. & Hook. f. [Ericaceae] – Flutterbush, Mountain-andromeda	-	Sansford 2012	Recorded in Australia, but location not specified (Randall 2007)
Pieris formosa (Wall.) D. Don [Ericaceae] – Himalaya andromeda	*Andromeda formosa* Wall., *Lyonia formosa* (Wall.) Hand.-Mazz., *Pieris bodinieri* H. Lév., *Pieris forrestii* Harrow, *Pieris huana* W.P. Fang	Kliejunas 2003; Inman et al. 2003	Recorded in Australia, but location not specified (Randall 2007)
Pieris japonica (Thunb.) D. Don ex G. Don [Ericaceae] – Japanese pieris	*Andromeda japonica* Thunb., *Lyonia polita* (W.W. Sm. & Jeffrey) Chun, *Lyonia popowii* (Palib.) Chun, *Pieris polita* W.W. Sm. & Jeffrey, *Pieris popowii* Palib., *Pieris*	Parke et al. 2004a, b; Husson et al. 2007	Recorded in Australia, but location not specified (Randall 2007)

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
	taiwanensis Hayata		
Pinus radiata D. Don [Pinaceae] – Monterey pine	*Pinus insignis* Douglas ex Loudon	Dick et al. 2014	NSW, VIC, QLD, SA, WA, ACT, TAS
Pittosporum tobira (Thunb.) W.T. Aiton [Pittosporaceae] – Australian laurel	-	Blomquist et al. 2015	
Pittosporum undulatum Vent. [Pittosporaceae] – Victorian box	-	Hüberli et al. 2006; Sansford et al. 2009	NSW, VIC, QLD, SA, WA, ACT, TAS, NT
Populus deltoides W. Bartram ex Marshall [Salicaceae] – Necklace poplar, eastern cottonwood	*Populus canadensis* Moench	Vettraino et al. 2010	NSW, ACT
Prumnopitys ferruginea (G. Benn. Ex D. Don) de Laub. [Podocarpaceae] (Only reported as a host of *Phytophthora kernoviae*)	-	Dick et al. 2014	Recorded in Australia, but location not specified (Randall 2007)
Prunus laurocerasus L. [Rosaceae] – Dwarf English laurel	-	Cave et al. 2008; Sansford et al. 2009	NSW, SA, VIC, TAS
Prunus lusitanica L. [Rosaceae] – Portuguese laurel cherry	-	Sansford et al. 2009	NSW, VIC, ACT, SA, TAS
Pseudotsuga menziesii (Mirb.) Franco [Pinaceae] – Douglas fir	*Abies menziesii* Mirb., *Abies mucronata* Raf., *Abies taxifolia* (Lamb) Poir., *Pinus douglasii* Sabine ex D. Don, *Pinus taxifolia* Lamb., *Pseudotsuga douglasii* (Sabine ex D. Don) Carrière, *Pseudotsuga mucronata* (Raf.) Sudw., *Pseudotsuga taxifolia* Britton	Davidson et al. 2002c	SA, NSW, TAS, ACT
Pyracantha koidzumii (Hayata) Rehder [Rosaceae] – Formosa firethorn	*Cotoneaster formosanus* Hayata, *Cotoneaster koidzumii* Hayata, *Cotoneaster taitoensis* Hayata, *Pyracantha formosana* Kaneh.	Briere et al. 2005; Sansford et al. 2009	SA
Quercus L. species [Fagaceae] – Beech	*Erythrobalanus* (Spach) O. Schwarz, *Macrobalanus* (Oerst.) O. Schwarz	COMTF 2015	SA, ACT, NSW, VIC, TAS, QLD
Quercus acuta Thunb. [Fagaceae] – Japanese evergreen oak	-	COMTF 2015	VIC
Quercus agrifolia Née [Fagaceae] – Coast live	*Quercus acroglandis* Kellogg, *Quercus pricei*	Hansen et al. 2003a; Garbelotto et al.	ACT

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
oak	Sudw.	2003; Scianna et al. 2003; Vettraino et al. 2008	
Quercus cerris L. [Fagaceae] – Turkey oak	-	Sansford et al. 2009; COMTF 2015	NSW, ACT, SA, VIC
Quercus chrysolepis Liebm. [Fagaceae] – Canyon live oak	*Quercus chrysophyllus* Kellogg, *Quercus crassipocula* Torr., *Quercus fulvescens* Kellogg, *Quercus wilcoxii* Rydb.	Murphy & Rizzo 2003	ACT
Quercus falcata Michx. [Fagaceae] – Southern red oak	*Quercus rubra* Sarg.	Brasier et al. 2004a	Recorded in Australia, but location not specified (Randall 2007)
Quercus ilex L. [Fagaceae] – Holm oak	*Quercus baloot* Griff.*	Denman et al. 2005	SA, ACT, NSW, TAS
Quercus kelloggii Newb. [Fagaceae] – Californian black oak	*Quercus californica* (Torr.) Cooper	Garbelotto et al. 2003; Scianna et al. 2003; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Quercus petraea (Matt.) Liebl. [Fagaceae] – Sessile oak	-	COMTF 2015	NSW
Quercus phillyraeoides A. Gray [Fagaceae] – Ubame oak	*Maesa singuliflora* H. Lév., *Quercus fokienensis* Nakai, *Quercus fooningensis* H.H. Hu & W.C. Cheng, *Quercus lichuanensis* W.C. Cheng, *Quercus myricifolia* H.H. Hu & W.C. Cheng, *Quercus singuliflora* A. Camus	FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
Quercus robur L. [Fagaceae]– English oak, Pedunculate oak	*Quercus pedunculata* Ehrh.	FERA 2012	SA, ACT, NSW, TAS, QLD, VIC
Quercus rubra L. [Fagaceae] – Northern red oak	*Quercus borealis* F. Michx., *Quercus maxima* (Marshall) Ashe	Sundheim et al. 2009	ACT
Quercus wislizeni A. DC. [Fagaceae] – Shreve oak	*Quercus parvula* Greene	Garbelotto et al. 2003; Scianna et al. 2003	Recorded in Australia, but location not specified (Randall 2007)
Rhamnus L. species [Rhamnaceae] – Buckthorn	*Oreoherzogia* W. Vent	Blomquist et al. 2015	QLD, ACT, NSW, TAS, VIC, SA, WA
Rhododendron L. species[Ericaceae] – Rhododendron	-	Garbelotto et al. 2003; Parke et al. 2004a; Tjosvold et al. 2005; Cave et al. 2008; Tsopelas et al. 2011; Dick et al. 2014	QLD, ACT, NSW, TAS, VIC, SA, WA

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Rhododendron catawbiense Michx. [Ericaceae] – Catawba rhododendron	-	Herrero et al. 2006	NSW
Rhododendron macrophyllum D. Don ex G. Don [Ericaceae]– California rose bay	-	Scianna et al. 2003; Goheen et al 2002	Recorded in Australia, but location not specified (Randall 2007)
Rhododendron ponticum L. [Ericaceae] – Common rhododendron	-	Purse et al. 2013	TAS, NSW, SA
Ribes laurifolium Jancz. [Grossulariaceae] – Bayleaf currant	-	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Rosa species (several different cultivars) [Rosaceae] – Rose	-	Cave et al. 2008; Sansford et al. 2009	SA, NSW, VIC, QLD, TAS, WA, ACT
Rosa californica Cham. & Schltdl. [Rosaceae] – Californian wild rose	*Rosa aldersonii* Greene	Vettraino et al. 2010	Recorded in Australia, but location not specified (Randall 2007)
Rosa gymnocarpa Nutt. [Rosaceae] – Californian wood rose	-	Hüberli et al. 2004	Recorded in Australia, but location not specified (Randall 2007)
Rosa rugosa Thunb. [Rosaceae] – Rugosa rose	*Rosa ferox* Lawrance, *Rosa pubescens* Baker	Sansford et al. 2009	SA
Rubus spectabilis Pursh [Rosaceae] – Salmonberry	*Rubus franciscanus* Rydb.	Cave et al. 2008	Recorded in Australia, but location not specified (Randall 2007)
Rubus ursinus Cham. & Schltdl. [Rosaceae] – Blackberry, Dewberry	*Rubus eastwoodianus* Rydb., *Rubus macropetalus* Douglas ex Hook., *Rubus sirbenus* L.H. Bailey, *Rubus vitifolius* Cham. & Schltdl.	COMTF 2015; Vettraino et al. 2010	Recorded in Australia, but location not specified (Randall 2007)
Salix caprea L. [Salicaceae] – Goat willow, Sallow	*Salix bakko* Kimura, *Salix coaetanea* Flod., *Salix hultenii* Flod.	Sansford et al. 2009; COMTF 2015	TAS, NSW, ACT, VIC
Sarcococca hookeriana Baill. var. *digyna* Franch. [Buxaceae] – Himalyan sweet box	*Myrsine chevalieri* H. Lév., *Pachysandra mairei* H. Lév., *Sarcococca humilis* Stapf	FERA 2012; Alexandra Schlenzig, SASA, personal communication 2012	Recorded in Australia, but location not specified (Randall 2007)
Schima superba Gardner & Champ. [Theaceae] – Chinese guger tree	*Schima confertiflora* Merr., *Schima kankaoensis* Hayata, *Schima liukiuensis* Nakai, *Schima xinyiensis* H.T. Chang & Z.Y. Su	Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
Schima wallichii (DC.) Korth. [Theaceae]	*Gordonia chilaunia* Buch.-Ham. ex D. Don, *Gordonia wallichii* DC., *Schima brevipes* Craib	COMTF 2015	NSW

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Sequoia Endl. species [Taxodiaceae] – Redwood	-	Scianna et al. 2003	ACT, SA, VIC, TAS, WA
Sequoia sempervirens (D. Don) Endl. [Taxodiaceae] – Coast redwood	*Sequoia gigantea* (Lindl.) Endl., *Taxodium sempervirens* D. Don	Maloney et al. 2002; Kliejunas 2003; Hansen et al. 2003a	ACT, VIC, SA, TAS, WA
Symphoricarpos Duhamel species [Caprifoliaceae] – Snowberry	-	Vettraino et al. 2010	TAS, NSW, VIC, SA, ACT
Syringa vulgaris L. [Oleaceae] – Lilac	-	Beales et al. 2004b	ACT, WA, NSW, TAS
Taxus baccata L. [Taxaceae] – Yew	*Taxus wallichiana* Zucc.	Lane et al. 2004	NSW, SA, TAS, ACT
Taxus brevifolia Nutt. [Taxaceae] – Pacific yew	*Taxus boursieri* Carrière, *Taxus lindleyana* A. Murray bis	Sansford et al. 2009; COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Torreya californica Torr. [Taxaceae] – California nutmeg	*Tumion californicum* (Torr.) Greene* *Torreya myristica* Hook.	Cave et al. 2008; Sansford et al. 2009; COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Toxicodendron diversilobum (Torr. & A. Gray) Greene [Anacardiaceae] – Pacific poison oak	*Rhus diversiloba* Torr. & A. Gray	Cave et al. 2008	QLD
Trachelospermum jasminoides (Lindl.) Lem. [Apocynaceae] – Star jasmine, Confederate jasmine	*Rhynchospermum jasminoides* Lindl., *Trachelospermum adnascens* Hance	COMTF 2015	QLD, NSW, ACT
Trientalis latifolia Hook. [Primulaceae] – Western star flower	-	Hüberli et al. 2003b	Not listed as occurring in Australia
Trillium ovatum Pursh [Melanthiaceae] – Western wake robin	-	COMTF 2015	Not listed as occurring in Australia
Tsuga heterophylla (Raf.) Sarg. [Pinaceae] – Western hemlock	*Abies heterophylla* Raf.	COMTF 2015; FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
Umbellularia californica (Hook. & Arn.) Nutt. [Lauraceae] – Californian bay laurel	-	Garbelotto et al. 2003; Scianna et al. 2003; Hansen et al. 2003a	SA
Vaccinium myrtillus L. [Ericaceae] – Bilberry	*Vaccinium oreophilum* Rydb.	Herrero et al. 2011	Recorded in Australia, but location not specified (Randall 2007)
Vaccinium ovatum Pursh [Ericaceae] – Californian huckleberry	-	Goheen et al. 2002; Davidson et al. 2003b; Scianna et al. 2003	VIC
Vaccinium parvifolium Sm. [Ericaceae] – Red	-	COMTF 2015	Recorded in Australia, but location not

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
huckleberry			specified (Randall 2007)
Vaccinium vitis-idaea L. [Ericaceae] – Cowberry	*Rhodococcum vitis-idaea* Avrorin, *Vaccinium jesoense* Miq.	COMTF 2015	Recorded in Australia, but location not specified (Randall 2007)
Vancouveria planipetala Calloni [Berberidaceae] – Redwood ivy	-	COMTF 2015	Not listed as occurring in Australia
Veronica spicata L. [Scrophulariaceae] – Spiked speedwell	*Pseudolysimachion spicatum* (L.) Opiz*, *Veronica hybrida* L.	COMTF 2015; APHIS 2012	NSW
Viburnum L. species [Caprifoliaceae] –Viburnum	*Actinotinus* Oliv., *Oreinotinus* Oerst.	Parke et al. 2004a, b; Tjosvold et al. 2005; Cave et al. 2008; Sansford et al. 2009; COMTF 2015; RAPRA 2012	SA, ACT, VIC, NSW, TAS
Viburnum davidii Franch. [Caprifoliaceae] – David viburnum	-	Osterbauer 2004	ACT
Viburnum farreri Stearn [Caprifoliaceae] – Fragrant viburnum	*Lonicera mongolica* J.F. Gmel., *Viburnum fragrans* Bunge	Osterbauer 2004	Recorded in Australia, but location not specified (Randall 2007)
Viburnum lantana L. [Caprifoliaceae] – Wayfaringtree viburnum	-	Osterbauer 2004	NSW
Viburnum opulus L. [Caprifoliaceae]– European cranberry, Bush viburnum	-	Osterbauer 2004	NSW, TAS, VIC
Viburnum plicatum Thunb. var. *tomentosum* Miq. [Caprifoliaceae] – Doublefile viburnum	*Viburnum tomentosum* Thunb	Osterbauer 2004	Recorded in Australia, but location not specified (Randall 2007)
Viburnum tinus L. [Caprifoliaceae] – Laurustinus	-	Vettraino et al. 2009	SA, ACT, VIC, TAS, NSW
Vinca L. species [Apocynaceae] – Periwinkle	-	COMTF 2015	QLD, NSW, VIC, WA, SA, TAS

*represents an accepted name on the Missouri Botanical Garden taxonomic database Tropicos (tropicos.org).

Appendix B: Additional quarantine pest data

Quarantine pest	***Phytophthora kernoviae*** Brasier, Beales & S.A. Kirk 2005
Synonyms	None
Common name(s)	Kernoviae bleeding canker, Kernoviae dieback, Kernoviae leaf blight
Main hosts	Multiple; including trees and non-trees
Distribution	New Zealand and the UK (England, Ireland, Scotland and Wales) (DEFRA 2008; Fichtner et al. 2012).
Quarantine pest	***Phytophthora nemorosa*** E.M. Hansen & Reeser 2003
Synonyms	None
Common name(s)	None
Main hosts	Multiple; including trees and non-trees
Distribution	The USA (California and Oregon) (Linzer et al. 2009; Yakabe et al. 2009).
Quarantine pest	***Phytophthora pseudosyringae*** T. Jung & Delatour 2003
Synonyms	None
Common name(s)	None
Main hosts	Multiple; including trees and non-trees
Distribution	England, Scotland, Wales (Scanu et al. 2012), Italy, Spain (Scanu et al. 2010), Germany, France, Romania (Jung et al. 2007), Poland (Olejarski et al. 2012), Norway (Talgø et al. 2012), the Netherlands (Jung 2009) and USA (Yakabe et al. 2009; Alaska (Reeser et al. 2011), California, Oregon (Jung et al. 2007; Linzer et al. 2009) and North Carolina (EPPO 2009).
Quarantine pest	***Phytophthora ramorum*** Werres, De Cock & Man in 't Veld 2001
Synonyms	None
Common name(s)	Ramorum bleeding canker, Ramorum leaf blight, Ramorum shoot dieback, Sudden larch death, Sudden oak death
Main hosts	Multiple; including trees and non-trees
Distribution	Belgium, Canada (British Columbia), Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, India, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Switzerland, Sweden, the UK (England, Ireland, Scotland and Wales) and the USA (Denman et al. 2009; EPPO 2012; FERA 2012; Sansford et al. 2009; Gomes & Amaro 2009; Mathew & Beena 2012). In the USA, *P. ramorum* occurs in California, Washington and Oregon. Infected nursery stock has also been detected in Alabama, Arkansas, Arizona, California, Colorado, Connecticut, Florida, Georgia, Louisiana, Maryland, Mississippi, North Carolina, New Jersey, New Mexico, New York, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, and Washington (Sansford et al. 2009; Cave et al. 2008; Henricot & Prior 2004). The known geographic distribution of *P. ramorum* is expanding, with ongoing new detections in nurseries and forests.

Appendix C: Biosecurity framework

Australia's biosecurity policies

The objective of Australia's biosecurity policies and risk management measures is the prevention or control of the entry, establishment or spread of pests and diseases that could cause significant harm to people, animals, plants and other aspects of the environment.

Australia has diverse native flora and fauna and a large agricultural sector, and is relatively free from the more significant pests and diseases present in other countries. Therefore, successive Australian Governments have maintained a conservative, but not a zero-risk, approach to the management of biosecurity risks. This approach is consistent with the World Trade Organization's (WTO's) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement).

The SPS Agreement defines the concept of an 'appropriate level of protection' (ALOP) as the level of protection deemed appropriate by a WTO Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory. Among a number of obligations, a WTO Member should take into account the objective of minimising negative trade effects in setting its ALOP.

Like many other countries, Australia expresses its ALOP in qualitative terms. Australia's ALOP, which reflects community expectations through Australian Government policy, is currently expressed as providing a high level of sanitary and phytosanitary protection, aimed at reducing risk to a very low level, but not to zero.

Consistent with the SPS Agreement, in conducting risk analyses Australia takes into account as relevant economic factors:

- the potential damage in terms of loss of production or sales in the event of the entry, establishment or spread of a pest or disease in the territory of Australia
- the costs of control or eradication of a pest or disease
- and the relative cost-effectiveness of alternative approaches to limiting risks.

Roles and responsibilities within Australia's quarantine system

Australia protects its human, animal and plant life or health through a comprehensive quarantine system that covers the quarantine continuum, from pre-border to border and post-border activities. The Australian Government Department of Health is responsible for human health aspects of quarantine. The Australian Government Department of Agriculture and Water Resources is responsible for animal and plant life or health.

Pre-border, Australia participates in international standard-setting bodies, undertakes risk analyses, develops offshore quarantine arrangements where appropriate, and engages with our neighbours to counter the spread of exotic pests and diseases.

At the border, Australia screens vessels (including aircraft), people and goods entering the country to detect potential threats to Australian human, animal and plant health.

The Australian Government also undertakes targeted measures at the immediate post-border level within Australia. This includes national co-ordination of emergency responses to pest and disease incursions. The movement of goods of quarantine concern within Australia's border is the responsibility of relevant state and territory authorities, which undertake inter– and intra–state quarantine operations that reflect regional differences in pest and disease status, as a part of their wider plant and animal health responsibilities.

Roles and responsibilities within the Department

The Australian Government Department of Agriculture and Water Resources is responsible for the Australian Government's animal and plant biosecurity policy development and the establishment of risk management measures. The Secretary of the department is appointed as the Director of Animal and Plant Quarantine under the *Quarantine Act 1908* (the Act).

The department takes the lead in biosecurity and quarantine policy development and the establishment and implementation of risk management measures across the biosecurity continuum, and:

- **Pre-border** conducts risk analyses, including IRAs, and develops recommendations for biosecurity policy as well as providing quarantine policy advice to the Director of Animal and Plant Quarantine
- **At the border** develops operational procedures, makes a range of quarantine decisions under the Act (including import permit decisions under delegation from the Director of Animal and Plant Quarantine) and delivers quarantine services
- **Post-border** coordinates pest and disease preparedness, emergency responses and liaison on inter– and intra–state quarantine arrangements for the Australian Government, in conjunction with Australia's state and territory governments.

Roles and responsibilities of other government agencies

State and territory governments play a vital role in the quarantine continuum. The department works in partnership with state and territory governments to address regional differences in pest and disease status and risk within Australia, and develops appropriate sanitary and phytosanitary measures to account for those differences. Australia's partnership approach to quarantine is supported by a formal Memorandum of Understanding that provides for consultation between the Australian Government and the state and territory governments.

Depending on the nature of the good being imported or proposed for importation, the department may consult other Australian Government authorities or agencies in developing its recommendations and providing advice.

As well as a Director of Animal and Plant Quarantine, the Act provides for a Director of Human Quarantine. The Australian Government Department of Health is responsible for human health aspects of quarantine and Australia's Chief Medical Officer within that department holds the position of Director of Human Quarantine. The Department of Agriculture and Water Resources may, where appropriate, consult with the Department of Health on relevant matters that may have implications for human health.

The Act also requires the Director of Animal and Plant Quarantine, before making certain decisions, to request advice from the Environment Minister and to take the advice into account when making those decisions. The Australian Government Department of the Environment is responsible under the *Environment Protection and Biodiversity Conservation Act 1999* for assessing the environmental impact associated with proposals to import live species. Anyone proposing to import such material should contact the Department of the Environment directly for further information.

When undertaking risk analyses, the Department of Agriculture and Water Resources consults with the Department of the Environment about environmental issues and may use or refer to the Department of the Environment's assessment.

Australian quarantine legislation

The Australian quarantine system is supported by Commonwealth, state and territory quarantine laws. Under the Australian Constitution, the Commonwealth Government does not have exclusive power to make laws in relation to quarantine, and as a result, Commonwealth and state quarantine laws can co-exist.

Commonwealth quarantine laws are contained in the *Quarantine Act 1908* and subordinate legislation including the *Quarantine Regulations 2000*, the *Quarantine Proclamation 1998*, the *Quarantine (Cocos Islands) Proclamation 2004* and the *Quarantine (Christmas Island) Proclamation 2004*.

The quarantine proclamations identify goods, which cannot be imported, into Australia, the Cocos Islands and or Christmas Island unless the Director of Animal and Plant Quarantine or delegate grants an import permit or unless they comply with other conditions specified in the proclamations. Section 70 of the *Quarantine Proclamation 1998*, section 34 of the *Quarantine (Cocos Islands) Proclamation 2004* and section 34 of the *Quarantine (Christmas Island) Proclamation 2004* specify the things a Director of Animal and Plant Quarantine must take into account when deciding whether to grant a permit.

In particular, a Director of Animal and Plant Quarantine (or delegate):

- must consider the level of quarantine risk if the permit were granted;
- must consider whether, if the permit were granted, the imposition of conditions would be necessary to limit the level of quarantine risk to one that is acceptably low;
- for a permit to import a seed of a plant that was produced by genetic manipulation—must take into account any risk assessment prepared, and any decision made, in relation to the seed under the *Gene Technology Act*; and
- may take into account anything else that he or she knows is relevant.

The level of quarantine risk is defined in section 5D of the *Quarantine Act 1908*. The definition is as follows:

reference in this Act to a *level of quarantine risk* is a reference to:

a) the probability of:

   i) a disease or pest being introduced, established or spread in Australia, the Cocos Islands or Christmas Island; and
   ii) the disease or pest causing harm to human beings, animals, plants, other aspects of the environment, or economic activities; and

b) the probable extent of the harm.

The *Quarantine Regulations 2000* were amended in 2007 to regulate keys steps of the import risk analysis process. The Regulations:

- define both a standard and an expanded IRA;
- identify certain steps, which must be included in each type of IRA;
- specify time limits for certain steps and overall timeframes for the completion of IRAs (up to 24 months for a standard IRA and up to 30 months for an expanded IRA);
- specify publication requirements;
- make provision for termination of an IRA; and
- allow for a partially completed risk analysis to be completed as an IRA under the Regulations.

The Regulations are available on the ComLaw website.

International agreements and standards

The process set out in the *Import Risk Analysis Handbook 2011* is consistent with Australia's international obligations under the SPS Agreement. It also takes into account relevant international standards on risk assessment developed under the International Plant Protection Convention (IPPC) and by the World Organisation for Animal Health (OIE).

Australia bases its national risk management measures on international standards where they exist and when they achieve Australia's ALOP. Otherwise, Australia exercises its right under the SPS Agreement to apply science-based sanitary and phytosanitary measures that are not more trade restrictive than required to achieve Australia's ALOP.

Notification obligations

Under the transparency provisions of the SPS Agreement, WTO Members are required, among other things, to notify other members of proposed sanitary or phytosanitary regulations, or changes to existing regulations, that are not substantially the same as the content of an international standard and that may have a significant effect on trade of other WTO Members.

Risk analysis

Within Australia's quarantine framework, the Australian Government uses risk analyses to assist it in considering the level of quarantine risk that may be associated with the importation or proposed importation of animals, plants or other goods.

In conducting a risk analysis, the department:

- identifies the pests and diseases of quarantine concern that may be carried by the good;

- assesses the likelihood that an identified pest or disease would enter, establish or spread; and
- assesses the probable extent of the harm that would result.

If the assessed level of quarantine risk exceeds Australia's ALOP, the department will consider whether there are any risk management measures that will reduce quarantine risk to achieve the ALOP. If there are no risk management measures that reduce the risk to that level, trade will not be allowed.

Risk analyses carried out by specialists within the department, may also involve relevant experts from state and territory agencies, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), universities and industry to access the technical expertise needed for a particular analysis.

Risk analyses are conducted across a spectrum of scientific complexity and available scientific information. An IRA is a type of risk analysis with key steps regulated under the *Quarantine Regulations 2000*. The department's assessment of risk may also take the form of a non-regulated analysis of existing policy or technical advice. Further information on the types of risk analysis is provided in the *Import Risk Analysis Handbook 2011.*

Glossary

Term or abbreviation	**Definition**
Additional declaration	A statement that is required by an importing country to be entered on a phytosanitary certificate and which provides specific additional information on a consignment in relation to regulated pests (FAO 2015).
Appropriate level of protection (ALOP)	The level of protection deemed appropriate by the Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory (WTO 1995).
Area	An officially defined country, part of a country or all or parts of several countries (FAO 2015).
Area of low pest prevalence	An area, whether all of a country, part of a country, or all parts of several countries, as identified by the competent authorities, in which a specific pest occurs at low levels and which is subject to effective surveillance, control or eradication measures (FAO 2015).
Arthropod	The largest phylum of animals, including the insects, arachnids and crustaceans.
Asexual reproduction	The development of new individual from a single cell or group of cells in the absence of meiosis.
Chlamydospore	An asexual reproductive structure providing a resting spore that can survive adverse conditions better than sporangia.
Clonal lineage	A population of asexually reproducing individuals descended from the same ancestor.
Consignment	A quantity of plants, plant products or other articles being moved from one country to another and covered, when required, by a single phytosanitary certificate (a consignment may be composed of one or more commodities or lots) (FAO 2015).
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO 2015).
Culturing	A technique that multiplies plant cells, tissues or organs under controlled conditions suitable for plant growth, allowing disease screening to take place.
Disease cycle	This is the sequence of events involved in disease development, including the stages of development of the pathogen and the effect of the disease on the host; the chain of events that occur between the time of infection and the final expression of disease (Shurtleff & Averre 1997).
Drenching	A technique used by quarantine authorities to remove organisms of quarantine concern. The technique involves the sufficient application of liquid to plant material to ensure adequate penetration of chemicals to control the risk of nematodes and fungi (Department of Agriculture 2006).
The department	The Australian Government Department of Agriculture and Water Resources.
Endangered area	An area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss (FAO 2015).
Endemic	Belonging to, native to, or prevalent in a particular geography, area or environment.
Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO 2015).
Equivalence (of phytosanitary terms)	The situation where, for a specified pest, different phytosanitary measures achieve a contracting party's appropriate level of protection (FAO 2015).

Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2015).
Fumigation	A method of pest control that completely fills an area with gaseous pesticides to suffocate or poison the pests within.
Heterothallic	Requiring two opposite mating types for sexual reproduction via oospores as opposed to homothallic species. Homothallism is thought to result in inbreeding or selfing with low rates of outcrossing (Shurtleff & Averre, 1997).
Heterothallism	Self-sterility; a sexual condition in which an individual produces only one kind of gamete. Used chiefly in reference to fungi and algae (Shurtleff & Averre, 1997).
Host	An organism that harbours a parasite, mutual partner, or commensal partner, typically providing nourishment and shelter.
Host range	Species capable, under natural conditions, of sustaining a specific pest or other organism (FAO 2015).
Hypha(e)	The basic vegetative unit of structure and function of most fungi; a largely microscopic tubular filament that increases in length by growth at its tip. New hyphae arise as lateral branches. Some can become specialized for given functions including producing spores, penetrating host tissues, etc. (Erwin & Ribeiro 1996).
Import permit	Official document authorising importation of a commodity in accordance with specified phytosanitary import requirements (FAO 2015).
Import risk analysis	An administrative process through which quarantine policy is developed or reviewed, incorporating risk assessment, risk management and risk communication.
Infection	The internal 'endophytic' colonisation of a plant, or plant organ, and is generally associated with the development of disease symptoms as the integrity of cells and/or biological processes are disrupted.
Infestation (of a commodity)	Presence in a commodity of a living pest of the plant or plant product concerned. Infestation includes infection (FAO 2015).
Inspection	Official visual examination of plants, plant products or other regulated articles to determine if pests are present or to determine compliance with phytosanitary regulations (FAO 2015).
Intended use	Declared purpose for which plants, plant products, or other regulated articles are imported, produced or used (FAO 2015).
Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment (FAO 2015).
International Standard for Phytosanitary Measures (ISPM)	An international standard adopted by the Conference of the Food and Agriculture Organization, the Interim Commission on Phytosanitary Measures or the Commission on Phytosanitary Measures, established under the IPCC (FAO 2015).
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO 2015).
Larva	A juvenile form of animal with indirect development, undergoing metamorphosis (for example, insects or amphibians).
Life cycle	Cyclical progression of stages in the growth and development of an organism (plant, animal, or pathogen) that occur between the appearance and reappearance of the same stage of the organism (Shurtleff & Averre 1997).
Mating Types	Compatible strains, usually designated + and – or A and B, necessary for sexual reproduction in heterothallic fungi (Shurtleff & Averre 1997).
Monocyclic	Having one cycle per growing season; no secondary infections (Shurtleff & Averre

	1997).
Mycelium	Tubular strands that make up the body of the fungal microorganism. In *Phytophthora*, mycelium is non-septate, but plugs, often called false septa, can be seen in old mycelium (Erwin & Ribeiro 1996).
National Plant Protection Organisation (NPPO)	Official service established by a government to discharge the functions specified by the IPPC (FAO 2015).
Official control	The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests (FAO 2015).
Oospore	Thick-walled, resting spore in the oomycetes that develops from a fertilized oosphere or by parthenogenesis (Shurtleff & Averre 1997).
Pathogen	A biological agent that can cause disease to its host.
Pathway	Any means that allows the entry or spread of a pest (FAO 2015).
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2015).
Pest categorisation	The process for determining whether a pest has or has not the characteristics of a quarantine pest or those of a regulated non-quarantine pest (FAO 2015).
Pest free area (PFA)	An area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained (FAO 2015).
Pest free place of production	Place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period (FAO 2015).
Pest free production site	A defined portion of a place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period and that is managed as a separate unit in the same way as a pest free place of production (FAO 2015).
Pest risk analysis (PRA)	The process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it (FAO 2015).
Pest risk assessment (for quarantine pests)	Evaluation of the probability of the introduction and spread of a pest and of the magnitude of the associated potential economic consequences (FAO 2015).
Pest risk assessment (for regulated non-quarantine pests)	Evaluation of the probability that a pest in plants for planting affects the intended use of those plants with an economically unacceptable impact (FAO 2015).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2015).
Pest risk management (for regulated non-quarantine pests)	Evaluation and selection of options to reduce the risk that a pest in plants for planting causes an economically unacceptable impact on the intended use of those plants (FAO 2015).
Pest status (in an area)	Presence or absence, at the present time, of a pest in an area, including where appropriate its distribution, as officially determined using expert judgement on the basis of current and historical pest records and other information (FAO 2015).
Phytosanitary Certificate	An official paper document or its official electronic equivalent, consistent with the model of certificates of the IPPC, attesting that a consignment meets phytosanitary import requirements (FAO 2015).

Phytosanitary certification	Use of phytosanitary procedures leading to the issue of a phytosanitary certificate (FAO 2015).
Phytosanitary measure	Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO 2015).
Phytosanitary procedure	Any official method for implementing phytosanitary measures including the performance of inspections, tests, surveillance or treatments in connection with regulated pests (FAO 2015).
Phytosanitary regulation	Official rule to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests, including establishment of procedures for phytosanitary certification (FAO 2015).
Polycyclic	A disease of which many cycles occur in one growing season, resulting in many secondary infections (Shurtleff & Averre 1997).
Polyphagous	Feeding on a relatively large number of hosts from different plant family and/or genera.
PRA area	Area in relation to which a pest risk analysis is conducted (FAO 2015).
Propagule	Any part of an organism capable of initiating independent growth when separated from the parent body (Shurtleff & Averre 1997).
Quarantine	Official confinement of regulated articles for observation and research or for further inspection, testing or treatment (FAO 2015).
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO 2015).
Regulated article	Any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved (FAO 2015).
Regulated non-quarantine pest	A non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the territory of the importing contracting party (FAO 2015).
Restricted risk	Risk estimate with phytosanitary measure(s) applied.
Soil	The loose surface material of the earth in which plants grow, in most cases consisting of disintegrated rock with an admixture of organic material (NAPPO 2003).
Sporangium/sporangia	Sack within which zoospores form, especially when water is cooled to about 10 °C below ambient temperature. In solid substrates, sporangia usually germinate by germ tubes (Erwin & Ribeiro 1996).
Sporulate, sporulation	To form or produce spores (Shurtleff & Averre 1997).
Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO 2015).
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures.
Stakeholders	Government agencies, individuals, community or industry groups or organizations, whether in Australia or overseas, including the proponent/applicant for a specific proposal, who have an interest in the policy issues.
Surveillance	An official process which collects and records data on pest occurrence or absence by surveying, monitoring or other procedures (FAO 2015).

Systems approach(es)	The integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of protection against regulated pests.
Tissue culture	The products of 'an in vitro technique of cultivating (propagating) cells, tissues, or organs in a sterile synthetic medium' (Shurtleff & Averre 1997); comprising plant cells, tissues or organs, sterile synthetic medium, and the vessel in which cells have been propagated.
Trash	Soil, splinters, twigs, leaves, and other plant material, other than fruit stalks.
Treatment	Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalisation (FAO 2015).
Unrestricted risk	Unrestricted risk estimates apply in the absence of risk mitigation measures.
Viable	Alive, able to germinate or capable of growth.
Zoospore	Spore that forms within the sporangium and exits through the terminal pore, has a tinsel and a whiplash flagellum, and is capable of swimming for several hours (Erwin & Ribeiro 1996).

References

Alexander, J 2012, 'The past, present and future of sudden oak death'. *Outlooks on pest management* 23: 72–76.

APHIS (Animal and Plant Health Inspection Service, United States Department of Agriculture) 'Federal Order Jan 25, 2012: Domestic quarantine for *Phytophthora ramorum*', DA-2012-03, aphis.usda.gov/plant_health/plant_pest_info/pram/downloads/pdf_files/SPRO_ percent20DA-2012-03.pdf.

APHIS (Animal and Plant Health Inspection Service, USA Department of Agriculture) 2008a, 'Federal Order May 15, Federal domestic quarantine order *Phytophthora ramorum*', DA-2008-20, nationalplantboard.org/docs/spro/spro_pr_2008_05_16.pdf.

APHIS (Animal and Plant Health Inspection Service, USA Department of Agriculture) 2008b, 'Federal Order March 03, Federal domestic quarantine order *Phytophthora ramorum*', DA-2008-11, nationalplantboard.org/docs/spro/spro_pr_2008_03_05.pdf.

Australia's Virtual Herbarium (AVH), 2014, 'Council of Heads of Australasian Herbaria (CHAH)', avh.chah.org.au/.

Aveskamp, MM & Wingelaar, GJ 2005, 'Elimination of *Phytophthora ramorum* in the tunnel composting process', *Sudden Oak Death Science Symposium II*, Monterey, CA, nature.berkeley.edu/comtf/pdf/Bibliography/47Aveskamp.pdf, accessed May 2012.

Beales, PA, Brokenshire, T, Barnes, AV, Barton, VC & Hughes, KJD 2004a, 'First report of ramorum leaf blight and dieback (*Phytophthora ramorum*) on *Camellia* species in the UK', *Plant Pathology*, 53: 524.

Beales, PA, Giltrap, PM, Webb, KM & Ozolina, A 2009, 'A further threat to UK health and bilberry (*Vaccinium myrtillus*) by *Phytophthora pseudosyringae*', *Plant Pathology*, *New Disease Reports*.

Beales, PA, Schlenzig, A & Inman, AJ 2004b, 'First report of ramorum bud and leaf blight (*Phytophthora ramorum*) on *Syringa vulgaris* in the UK', *Plant Pathology*, 53: 525.

Birch, PR & Whisson, SC 2001, '*Phytophthora infestans* enters the genomics era', *Molecular Plant Pathology*, 2: 257–263.

Blair, JE, Coffey, MD, Park, SY, 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.

Blanco, FA & Judelson, HS (2005) 'A bZIP transcription factor from *Phytophthora* interacts with a protein kinase and is required for zoospore motility and plant infection', *Molecular Microbiology*, 56: 638–648.

Blomquist, C, Irving, T, Osterbauer, N & Reeser, P 2005, '*Phytophthora hibernalis*: a new pathogen of *Rhododendron* and evidence of cross amplification with two PCR detection assays for *Phytophthora ramorum*', *Plant Health Progress*, doi: 10.1094/PHP-2005-0728-01-

Blomquist, CL, Rooney-Latham, S & Soriano, MC 2012, 'First report of *Phytophthora ramorum* causing a leaf spot on *Loropetalum chinense*, Chinese fringe flower in California', *Plant Disease*, 96: 1829.2.

Blomquist, CL, Yakabe, LE, Rooney-Latham, S, McRoberts, N & Thomas, CS 2015, 'Detection of *Phytophthora ramorum* in Nurseries and Forest Lands in California 2004–2009', *Plant Disease* (In Press), apsjournals.apsnet.org/doi/pdfplus/10.1094/PDIS-12-14-1302-RE.

Brasier, C & Webber, J 2012, 'Natural stem infection of Lawson cypress (*Chamaecyparis lawsoniana*) caused by *Phytophthora ramorum*', *New Disease Reports*, 25–26.

Brasier, C 2007, '*Phytophthora ramorum* + *P. kernoviae* = International Biosecurity Failure', *Proceedings of the Sudden Oak Death Third Science Symposium*, General technical report PSW-GTR-214, 133–139.

Brasier, C, Beales, P, Kirk, S, Barton, V, Giltrap, P, Griffin, R, Hughes, K, Lane, C, Rose, J, Denham, S & Webber, J 2004c, 'A new *Phytophthora* species affecting European Beech (*Fagus sylvatica*) and *Rhododendron* in the UK' [Poster], *Phytophthora ramorum*: A Review of North American and European Activity, California Oak Mortality Task Force Annual Meeting, March 10, 2004.

Brasier, C, Brown, A, Rose, J & Kirk, S 2007, 'Infection of tree stems by zoospores of *Phytophthora ramorum* and *P. kernoviae*' [Abstract], *Sudden Oak Death Science Symposium III,* nature.berkeley.edu/comtf/sodsymposium/PDF/Abstracts/ Infection percent20of percent20Tree percent20Stems percent20by percent20Zoospores-Brasier.pdf.

Brasier, C, Rose, J, Kirk, S, Denman, S & Webber, J 2006, 'Comparative host range and aggressiveness of *Phytophthora ramorum* and *Phytophthora kernoviae* sp. *nov*. on North American and European trees', *Proceedings of the Sudden Oak Death Second Science Symposium: the State of Our Knowledge,* General technical report PSW-GTR-196, 109–111.

Brasier, CM & Webber, J 2010, 'Sudden larch death', *Nature*, 466: 824–825.

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

Brasier, CM, Beales, PA, Kirk, SA, Denman, S & Rose, J 2005, '*Phytophthora kernoviae* sp. *nov*., an invasive pathogen causing bleeding stem lesions on forest trees and foliar necrosis of ornamentals in the UK', *Mycological Research*, 109: 853–859.

Brasier, CM, Denman, S, Brown, A & Webber, JA 2004a, 'Sudden oak death (*Phytophthora ramorum*) discovered on trees in Europe', *Mycological Research*, 108: 1107–1110.

Brasier, CM, Denman, S, Rose, J, Kirk, SA, Hughes, KJD, Griffin, RL, Lane, CR, Inman, JA & Webber, JF 2004b, 'First report of ramorum bleeding canker on *Quercus falcata* caused by *Phytophthora ramorum*', *Plant Pathology*, 53: 804.

Brasier, CM, Vettraino, AM, Chang, TT & Vannini, A 2010, '*Phytophthora lateralis* discovered in an old growth *Chamaecyparis* forest in Taiwan', *Plant Pathology*, 59: 595–603.

Briere, SC, Llewellyn, S & Kristjansson, G 2005, 'First report of *Pyracantha koidzumii* as a new host for sudden oak death caused by *Phytophthora ramorum*', *Sudden Oak Death Science Symposium II*, Monterey, CA.

Browning, M, Englander, L, Tooley, PW & Berner, D 2008, 'Survival of *Phytophthora ramorum* hyphae after exposure to temperature extremes and various humidities', *Mycologia*, 100: 236–245.

CABI 2014, '*Phytophthora ramorum* Datasheet', Invasive species compendium, CAB International, cabi.org/isc/datasheet/40991#20063115680.

Cave, GL, Randall-Schadel, B & Redlin, S 2008, 'Risk Analysis for *Phytophthora ramorum*' *Causal agent of sudden oak death, ramorum leaf blight, and ramorum dieback*. United States Department of Agriculture Animal and Plant Health Inspection Service Plant Protection and Quarantine. dpm.ifas.ufl.edu/plant_pest_risk_assessment/ALS6942_docs/pra-cphst-081.pdf.

Cave, GL, Randall-Schadel, BL & Redlin, SC 2005, 'Risk analysis for *Phytophthora ramorum*, causal agent of *phytophthora* canker (sudden oak death), ramorum leaf blight, and ramorum dieback', USDA, APHIS, PPQ, Center for Plant Health Science and Technology, Plant Epidemiology and Risk Analysis Laboratory.

Chastagner, GA & Riley, KL 2010, 'First report of *Phytophthora ramorum* infecting California red fir in California', *Plant Disease*, 94: 1170.

Chastagner, GA, Riley, K & Dart, N 2008, 'Recovery of *Phytophthora ramorum* from mistletoe and California bay inflorescences and possible implications relating to disease spread', *Proceedings of the Sudden Oak Death Symposium III*, Santa Rosa, California.

Chimento, A, Cacciola, SO & Garbelotto, M 2012, 'Detection of mRNA by reverse-transcription PCR as an indicator of viability in *Phytophthora ramorum*', *Forest Pathology*, 42: 14–21.

Cobb, RC, Meentemeyer, RK & Rizzo, DM 2010, 'Apparent competition in canopy trees determined by pathogen transmission rather than susceptibility', *Ecology*, 91: 327–333.

Colburn, GC, Sechler, KE & Shiskoff, N 2005, 'Survivability and pathogenicity of *Phytophthora ramorum* chlamydospores in soil', *Phytopathology*, 95:S20.

Commonwealth of Australia 2001, Australian Natural Resources Atlas and Data Library, environment.gov.au/atlas.

COMTF 2015, California Oak Mortality Task Force, accessed September 2015, suddenoakdeath.org/.

Cooke, DEL, Drenth, A, Duncan, JM, Wagels, G & Brasier, CM 2000, 'A molecular phylogeny of *Phytophthora* and related oomycetes', *Fungal Genetics and Biology*, 30: 17–32.

Cushman, JH & Meentemeyer, RK 2008, 'Multi-scale patterns of human activity and the incidence of an exotic forest pathogen', *Journal of Ecology*, 96: 766–776.

Dart, NL, Chastagner, GA 2007, 'Estimated economic losses associated with the destruction of plants due to *Phytophthora ramorum* quarantine efforts in Washington State', *Plant Management* Network, *Plant Health Progress*, accessed August 2007, doi:10.1094/PHP-2007-0508-02-RS.

Dart, NL, Chastagner, GA, Rugarber, EF & Riley, KL 2007, 'Recovery frequency of *Phytophthora ramorum* and other *Phytophthora* species in the soil profile of ornamental retail nurseries', *Plant Disease*, 91: 1419–1422.

Davidson, JM & Shaw, CG 2003, 'Pathways of movement for *Phytophthora ramorum*, the causal agent of Sudden Oak Death', *Sudden Oak Death Online Symposium*, doi:10.1094/SOD-2003-TS, apsnet.org/online/SOD.

Davidson, JM, Garbelotto, M, Koike, ST & Rizzo, DM 2002c, 'First report of *Phytophthora ramorum* on Douglas fir in California', *Plant Disease*, 86: 1274.

Davidson, JM, Maloney, PE, Wickland, AC, Morse, AC, Jensen, CE & Rizzo, DM 2002b, 'Transmission of *Phytophthora ramorum* via *Umbellularia californica* (California bay) leaves in California oak woodlands' [Abstract], *Proceedings of the Sudden Oak Death, A Science Symposium*, 9.

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.

Davidson, JM, Rizzo, DM, Garbelotto, M, Tjosvold, S & Slaughter, GW 2002a, '*Phytophthora ramorum* and sudden oak death in California: II Transmission and survival', *Fifth Symposium on California Oak Woodlands,* General Technical Report PSW-GTR-184, 741–749.

Davidson, JM, Rizzo, DM, Garbelotto, M, Tjosvold, S, Slaughter, GW & Wickland, C 2003a, 'Evidence for aerial transmission of *Phytophthora ramorum* among *Quercus* and *Lithocarpus* in California woodlands', In: '*Phytophthora* in Forests and Natural Ecosystems'. 2nd International IUFRO Meeting on *Phytophthora* in Forests and Natural Ecosystems, Albany, Western Australia. McComb, JA, Hardy, GEJ &Tommerup, IC (eds.), Murdoch University Print, Perth, Australia, 108–114.

Davidson, JM, Werres, S, Garbelotto, M, Hansen, EM & Rizzo, DM 2003b, '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.

Davis, FW, Borchert, M, Meentemeyer, RK, Flint, A & Rizzo, DM 2010, 'Pre-impact forest composition and ongoing tree mortality associated with sudden oak death in the Big Sur region; California', *Forest Ecology and Management*, 259: 2342–2354.

de Hoop, B, de Gruyter, H, de Haas, A, Horn, N, Wingelaar, J, Steeghs, M 2002, 'Report of a PRA for *Phytophthora ramorum*', 19pp.

De Merlier, D, Chandelier, A & Cavelier, M 2003, 'First Report of *Phytophthora ramorum* on *Viburnum bodnantense* in Belgium', *Plant Disease*, 87: 203.

DEFRA (Department for Environment, Forestry and Rural Affairs) 2004, '*Phytophthora ramorum* epidemiology: sporulation potential, dispersal, infection, latency and survival', Final Project Report PH0194, accessed December 2004, defra.gov.uk/science/project_data/DocumentLibrary/PH0194/ PH0194_2004_FRP.pdf.

DEFRA (Department for Environment, Forestry and Rural Affairs) 2008, '*Phytophthora ramorum*. A practical guide for established parks and gardens, amenity landscape and woodland gardens', DEFRA, London UK, accessed May 2011, fera.defra.gov.uk/plants/publications/documents/factsheets/pramparks.pdf.

Dehnen-Schmutz, K, Holdenrieder, O, Jeger, MJ & Pautasso, M 2010, 'Structural change in the international horticultural industry: some implications for plant health', *Scientia Horticulturae*, 125: 1–15.

Denman, S, Kirk, S, Whybrow, A, Orton, E & Webber, JF 2006, '*Phytophthora kernoviae* and *P. ramorum*: host susceptibility and sporulation potential on foliage of susceptible trees', *EPPO Bulletin*, 36: 373–376.

Denman, S, Kirk, SA, Brasier, CM, Barton, VC, Hughes, KJD & Webber, JF 2005, '*Phytophthora ramorum* on *Quercus ilex* in the United Kingdom', *Plant Disease*, 89: 241.

Denman, S, Kirk, SA, Moralejo, E & Webber, JF 2009, '*Phytophthora ramorum* and *Phytophthora kernoviae* on naturally infected asymptomatic foliage', *OEPP/EPPO Bulletin*, 39: 105–111.

Denman, S, Moralejo, E, Kirk, SA, Orton, E & Whybrow, A 2008, 'Sporulation of *Phytophthora ramorum* and *P. kernoviae* on asymptomatic foliage and fruit', *Proceedings of the Sudden Oak Death 3rd Science Symposium*, General technical report PSW-GTR-214, 201–208.

Denman, S, Rose, J & Slippers, B 2007, '*Phytophthora pseudosyringae* on European beech and hornbeam in the UK' [Poster], The Fourth IUFRO Working Party Meeting: '*Phytophthoras in Forests and Natural Ecosystems*', Monterey, California, USA, nature.berkeley.edu/IUFRO2007/phytophthora/tnp/denman_poster.pdf.

Department of Agriculture 2006, *Industry Advice Notice no. 2006/19: Advanced Nursery Stock Mature Trees – Singapore*, AQIS Horticulture Exports Program, Department of Agriculture website, daff.gov.au/biosecurity/export/plants-plant-products/ian/06/19.

Diana, G, Pane, A, Raudino, F, Cooke, DEL, Cacciola, SO, Magnano di San Lio, G 2006, 'A decline of beech trees caused by *Phytophthora pseudosyringae* in Central Italy', In: '*Progress in Research on Phytophthora Diseases of Forest Trees*', Brasier, C, Jung, T & Oßwald, W (eds), HMSO, Norwich, 142–144.

Dick, M & Parke, JL 2012, '*Phythophthora kernoviae*', *forest Phytophthoras*, 2 (1), doi: 10.5399/osu/fp.2.1.3051.

Dick, MA, Williams, NM, Bader, MKF, Gardner, JF & Bulman, LS 2014, 'Pathogenicity of *Phytophthora pluvialis* to *Pinus radiata* and its relation with red needle cast disease in New Zealand', *New Zealand Journal of Forestry Science* 44 (6): 1–12.

Dick, MW 2001, '*Straminipilous fungi: Systematics of the Peronosporomycetes including accounts of the marine straminipilous protists, the plasmodiophorids and similar organisms*', Kluwer Academic Publishers, Dordrecht.

DiLeo, MV, Bostock, RM & Rizzo, DM 2009, '*Phytophthora ramorum* does not cause physiologically significant systemic injury to California bay laurel, its primary reservoir host', *Phytopathology*, 99: 1307–1311.

Donahoo, R, Blomquist, CL, Thomas, SL, Moulton, JK, Cooke, DEL & Lamour, KH 2006, '*Phytophthora foliorum* sp nov., a new species causing leaf blight of azalea', *Mycological Research*, 110: 1309–1322.

Durán, A, Gryzenhout, M, Slippers, B, Ahumada, R, Rotella, A, Flores, F, Wingfield, BD & Wingfield, MJ 2008, '*Phytophthora pinifolia* sp. *nov* associated with a serious needle disease of *Pinus radiata* in Chile', *Plant Pathology*, 57: 715–727.

EFSA (European Food Safety Authority) 2011, 'Scientific Opinion on the Pest Risk Analysis on *Phytophthora ramorum* prepared by the FP6 project RAPRA', *The EFSA Journa*l, 19 (6): 2186–186EF, doi:10.2903/j.efsa.2011.2186.

EPPO (European and Mediterranean Plant Protection Organization) 2009, 'First report of *Phytophthora psuedosyringae* on *Vaccinium myrtillus* in the United Kingdom', EPPO Reporting Service No. 2009/162.

EPPO (European and Mediterranean Plant Protection Organization) 2011, '*Phytophthora ramorum* on *Larix* species in the United Kingdom' Reporting Service 2011, no. 5 2011/113, archives.eppo.int/EPPOReporting/2011/Rse-1105.pdf.

EPPO (European and Mediterranean Plant Protection Organization) 2012. 'European and Mediterranean Plant Protection Organisation Alert List – *Phytophthora ramorum*', accessed July 2012, eppo.int/QUARANTINE/Alert_List/alert_list.htm.

EPPO (European and Mediterranean Plant Protection Organization) 2013, 'Diagnostics: PM 7/112 (1) *Phytophthora kernoviae*', *EPPO Bulletin*, 43: 81–93.

Erwin, DC & Ribeiro, OK 1996, '*Phytophthora diseases worldwide*', American Phytopathological Society Press, St. Paul, MN 562.

FAO (Food and Agricultural Organization of the United Nations) 1995, '*International Standards for Phytosanitary Measures (ISPM) No. 4: Requirements for the establishment of pest free areas*', Secretariat of the International Plant Protection Convention, Rome, Italy.

FAO (Food and Agricultural Organization of the United Nations) 1999, '*International Standards for Phytosanitary Measures (ISPM) No. 10: Requirements for the establishment of pest free places of production and pest free production sites*', Secretariat of the International Plant Protection Convention, Rome, Italy.

FAO (Food and Agricultural Organization of the United Nations) 2007, '*International Standards for Phytosanitary Measures (ISPM) No. 2: Framework for pest risk analysis*', Secretariat of the International Plant Protection Convention, Rome, Italy.

FAO (Food and Agricultural Organization of the United Nations) 2013, '*International Standards for Phytosanitary Measures (ISPM) No. 11: Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms*', Secretariat of the International Plant Protection Convention, Rome, Italy.

FAO (Food and Agricultural Organization of the United Nations) 2015, '*International Standards for Phytosanitary Measures (ISPM) No. 5: Glossary of phytosanitary terms*', Secretariat of the International Plant Protection Convention, Rome, Italy.

FERA (The Food and Environment Research Agency) 2012, 'FERA list of natural hosts for *Phytophthora ramorum* with symptom and location', updated July 2012, accessed September 2012, fera.defra.gov.uk/plants/plantHealth/pestsDiseases/phytophthora/documents/pRamorumHost.pdf.

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

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* species in UK woodlands', *Plant Disease*, 95: 13–8.

Fichtner, EJ, Rizzo, DM, Kirk, SA & Webber, JF 2012, 'Infectivity and sporulation potential of *Phytophthora kernoviae* to select North American native plants', *Plant Pathology*, 61: 224–233.

Fichtner, EJ, Rizzo, DM, Kirk, SA, Whybrow, A & Webber, J 2007b, 'Root associations of *Phytophthora ramorum* and *Phytophthora kernoviae* in UK woodlands' [Abstract], In: 4th IUFRO *Phytophthora*s in Forests & Natural Ecosystems 2007, Meeting Abstracts, 54–55.

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

Garbelotto, M & Rizzo, DM 2005, 'A California-based chronological review (1995–2004) of research on *Phytophthora ramorum*, the causal agent of sudden oak death', *Phytopathologia Mediterranea*, 44: 127–143.

Garbelotto, M 2003, 'Providing a solution composting as a control for sudden oak death disease', *Biocycle*, 44: 53–56.

Garbelotto, M, Davidson, JM, Ivors, K, Maloney, PE, Hüberli, D, Koike, ST & Rizzo, DM 2003, 'Non-oak native plants are main hosts for sudden oak death pathogen in California', *California Agriculture* 57: 18–23.

Garbelotto, M, Rizzo, DM & Davidson, JM 2001, 'Studies in the genetics of a new *Phytophthora* species associated with sudden oak death in California', *Phytopathology*, 91: S110.

Giltrap, PM, Hughes, KJD, Barton, VC, Hobden, E, Barber, P & Izzard, K 2007, '*Phytophthora ramorum* on three new hosts detected using on-site diagnostics', *Plant Pathology*, 56: 728.

Giltrap, PM, Inman, AJ, Barton, VC, Barnes, AV, Lane, CR, Hughes, KJD, Tomlinson, J, Dean, ML & Izzard, K 2004, 'First report of ramorum dieback (*Phytophthora ramorum*) on *Hamamelis virginiana* in the UK', *New Disease Reports*, 9: 11.

Goheen, EM & Frankel, SJ 2009, '*Phytophthora*s in forests and natural ecosystems', *Proceedings of the 4th Meeting of the International Union of Forest Research Organizations* (IUFRO) Working Party S07.02.09, Monterey, California, USA, General Technical Report PSW-GTR-221, 47–53. fs.fed.us/psw/publications/documents/psw_gtr221/psw_gtr221.pdf.

Goheen, EM, Hansen, E, Kanaskie, A, Osterbauer, N, Parke, J, Pscheidt, J & Chastagner, G 2006a, 'Sudden Oak Death and *Phytophthora ramorum*', In: *A guide for forest managers, Christmas tree growers, and forest-tree nursery operators in Oregon and Washington,* EM 8877.

Goheen, EM, Hansen, EM, Kanaskie, A, McWilliams, MG, Osterbauer, N & Sutton, W 2002, 'Sudden oak death caused by *Phytophthora ramorum* in Oregon', *Plant Disease*, 86: 441.

Goheen, EM, Kanaskie, A, Parke, J, Roth, M, Osterbauer, N & Trippe, A 2006b, 'Applications of fungicides to protect four hosts from foliar infection by *Phytophthora ramorum* in Curry County, Oregon', *Proceedings of the Sudden Oak Death Second Science Symposium: The State of Our Knowledge*, General technical report PSWGTR-196, 513–514.

Gomes, MJ & Amaro, PT 2009, 'Occurrence of *Phytophthora ramorum* in Portugal on *Viburnum* spp', *Revista de Ciências Agrárias*, 31(2): 105–111.

Goss, EM, Carbone, I & Grünwald, NJ 2009a, 'Ancient isolation and independent evolution of the three clonal lineages of the exotic sudden oak death pathogen *Phytophthora ramorum*', *Molecular Ecology*, 18: 1161–1174.

Goss, EM, Larsen, M, Chastagner, GA, Givens, DR & Grünwald, NJ 2009b, 'Population genetic analysis infers migration pathways of *Phytophthora ramorum* in US nurseries', *PLoS Pathogens*, 5: 1–12.

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 (2008c) *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, Garbelotto, M, Goss, EM, Heungens, K & Prospero, S 2012, Emergence of the sudden oak death pathogen *Phytophthora ramorum*, *Trends in microbiology*, 20: 3: 131–138.

Grünwald, NJ, Goss, E, Ivors, K, Garbelotto, M, Martin, FN, Prospero, S, Hansen, E, Bonants, PJM, Hamelin, RC, Chastagner, G, Werres, S, Rizzo, DM, Abad, G, Beales, P, Bilodeau, GJ, Blomquist, CL, Brasier, C, Brière, SC, Chandelier, A, Davidson, JM, Denman, S, Elliott, M, Frankel, SJ, Goheen, EM, de Gruyter, H, Heungens, K, Kanaskie, A, McWilliams, MG, Man in 't Veld, W, Moralejo, E, Osterbauer, NK, Palm, ME, Parke, JL, Perez Sierra, AM, Shamoun, SF, Shishkoff, N, Tooley, PW, Vettraino, AM, Webber, J, Widmer, TL & James, D 2009, 'Standardizing the nomenclature for clonal lineages of the sudden oak death pathogen, *Phytophthora ramorum*', *Phytopathology*, 99: 792–795.

Grünwald, NJ, Goss, EM, Larsen, MM, Press, CM, McDonald, VT, Blomquist, CL & Thomas, SL 2008a, 'First report of the European lineage of *Phytophthora ramorum* on *Viburnum* and *Osmanthus* species in a California Nursery', *Plant Disease*, 92: 314.

Grünwald, NJ, Kitner, M, McDonald, V & Goss, E 2008b, 'Susceptibility in *Viburnum* to *Phytophthora ramorum*', *Plant Disease*, 92: 210–214.

Grünwald, 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, E, Reeser, P, Davidson, JN, Garbelotto, M, Ivors, K, Douhan, L & Rizzo, DM 2003a, '*Phytophthora nemorosa*, a new species causing cankers and leaf blight of forest trees in California and Oregon, USA', *Mycotaxon*, 88: 129–138.

Hansen, EM 2008, 'Alien forest pathogens: *Phytophthora* species are changing world forests', *Boreal Environment Research*, 13 (Supplement A): 33–41.

Hansen, EM, Goheen, DJ, Jules, ES & Ullian, B 2000, 'Managing Port-Orford cedar and the introduced pathogen *Phytophthora lateralis*', *Plant Disease*, 84: 4–13.

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.

Hansen, EM, Parke, JL & Sutton, W 2005, 'Susceptibility of Oregon forests trees and shrubs to *Phytophthora ramorum*: a comparison of artificial inoculation and natural infections', *Plant Disease*, 89: 63–70.

Hansen, EM, Reeser, PW, Sutton, W, Winton, LM & Osterbauer, N 2003b, 'First record of A1 mating type of *Phytophthora ramorum* in North America', *Plant Disease*, 87: 1267.

Hansen, EM, Sutton, W, Parke, J & Linderman, R 2002, '*Phytophthora ramorum* and Oregon forest trees—one pathogen, three diseases' [Abstract], *Proceedings of the Sudden Oak Death, A Science Symposium*, USDA Forest Service and University of California, Berkeley 78–79.

Harnik, TY, Mejia-Chang, M, Lewis, J & Garbelotto, M 2004, 'Efficacy of heat-based treatments in eliminating the recovery of the sudden oak death pathogen (*Phytophthora ramorum*) from infected California bay laurel leaves', *HortScience*, 39: 1677–1680.

Hayden, K, Rickard, H & Garbelotto, M 2008, 'Correlating *Phytophthora ramorum* infection rate and lesion expansion in tanoak', *Proceedings of the 3rd Sudden Oak Death Science Symposium*, USDA Forest Service, Albany, CA, USA, 371–372.

Henricot, B & Prior, C 2004, '*Phytophthora ramorum*, the cause of sudden oak death or ramorum leaf blight and dieback', *Mycologist*, 18: 151–156.

Herrero, ML, Toppe, B & Brurberg, MB 2011, 'First Report of *Phytophthora ramorum* causing shoot dieback on bilberry (*Vaccinium myrtillus*) in Norway', *Plant Disease*, 95: 355.

Herrero, ML, Toppe, B, Klemsdal, SS & Stensvand, A 2006, 'First report of *Phytophthora ramorum* in ornamental plants in Norway', *Plant Disease*, 90: 1458.

Hong, C, Richardson, PA & Kong, P 2008, 'Pathogenicity to ornamental plants of some existing species and new taxa of *Phytophthora* from irrigation water', *Plant Disease*, 92: 1201–1207.

Hood IA, Williams NM, Dick MA, Arhipova N, Kimberley MO, Scott PM, Gardner Judy F, 2014, 'Decline in vitality of propagules of *Phytophthora pluvialis* and *Phytophthora kernoviae* and their inability to contaminate or colonise bark and sapwood in *Pinus radiata* export log simulation studies', *New Zealand Journal of Forestry Science*, 44: 7.

Hüberli, D & Garbelotto, M 2012, '*Phytophthora ramorum* is a generalist plant pathogen with differences in virulence between isolates from infectious and dead-end hosts', *Forest Pathology*, 41: 1–6.

Hüberli, D, Ivors, KL, Smith, A, Tse, JG & Garbelotto, M 2005, 'First report of foliar infection of *Maianthemum racemosum* by *Phytophthora ramorum*', *Plant Disease*, 89: 204.

Hüberli, D, Reuther, KD, Smith, A, Swain, S & Tse, JG 2004, 'First report of foliar infection of *Rosa gymnocarpa* by *Phytophthora ramorum*', *Plant Disease*, 88: 430.

Hüberli, D, Van Sant, W, Swain, S, Davidson, J & Garbelotto, M 2003a, 'Susceptibility of *Umbellularia californica* to *Phytophthora ramorum*' [Abstract], *Eighth International Congress of Plant Pathology*, Christchurch, New Zealand 268.

Hüberli, D, Van Sant-Glass, W, Tse, JG & Garbelotto, M 2003b, 'First report of foliar infection of starflower by *Phytophthora ramorum*', *Plant Disease*, 87: 599.

Hüberli, D, Wilkinson, C, Smith, MA, Meshriy, M, Harnik, TY & Garbelotto, M 2006, '*Pittosporum undulatum* is a potential Australian host of *Phytophthora ramorum*', *Australasian Plant Disease Notes*, 1: 19–21.

Hughes, K, Griffin, R, Boonham, N & Inman, A 2005, 'Development of molecular diagnostics for *Phytophthora kernoviae* a new *Phytophthora* threatening U.K. trees, woodlands, and ornamental plants', *The proceedings of the Sudden Oak Death Second Science Symposium: The State of Our Knowledge*, General Technical Report PSW-GTR-196, 556–557.

Hughes, KJD, Giltrap, PM, Barton, VC, Hobden, E, Tomlinson, JA & Barber, P 2006, 'On-site real-time PCR detection of *Phytophthora ramorum* causing dieback of *Parrotia persica* in the UK', *New Disease Reports*, 13: 11.

Husson, C, Delatour, C, Frey, P, Marçais, B, Saurat, C & Schenck, N 2007, 'First report of *Phytophthora ramorum* on ornamental plants in France', *Plant Disease*, 91: 1359.

Hwang, J, Jeffers, SN & Oak, SW 2007, 'Occurrence and distribution of *Phytophthora pseudosyringae* in forest streams of North Carolina', *Phytopathology*, 97: S49.

Hyder, N, Coffey, MD & Stanghellini, ME 2009, 'Viability of oomycetes propagules following ingestion and excretion by fungus gnats, shore flies, and snails', *Plant Disease*, 93:720–726.

IBIS World 2008, *Plant nurseries in Australia*, IBISWorld Industry Report A0111, accessed April 2014, tools.afr.com/search/_files percent5Cpdf percent5Csamplereport.pdf.

Inman, AJ, Townend, VC, Barnes, AV, Lane, CR, Hughes, KJD, Griffin, RL & Eales, SJ 2003, 'First report of ramorum dieback (*Phytophthora ramorum*) on *Pieris* in England', *New Disease Reports*, 7: 7.

Ireland, KB, Hardy, GESJ & Kriticos, DJ 2013, Combining Inferential and Deductive Approaches to Estimate the Potential Geographical Range of the Invasive Plant Pathogen, *Phytophthora ramorum*. *PloS one*, 8: 5: e63508.

Ivors, K, Garbelotto, M, Vries, IDE, Ruyter-Spira, C, Hekkert, BTE, Rosenzweig, N & Bonants, P 2006, 'Microsatellite markers identify three lineages of *Phytophthora ramorum* in US nurseries, yet single lineages in US forest and European nursery populations', *Molecular Ecology*, 15: 1493–1505.

Ivors, KI, Hayden, KJ, Bonants, PJM, Rizzo, DM & Garbelotto, M 2004, 'AFLP and phylogenetic analyses of North American and European populations of *Phytophthora ramorum*', *Mycological Research*, 108: 378–392.

Jeger, MJ, Pautasso, M, Holdenrieder, O & Shaw, MW 2007, 'Modelling disease spread and control in networks: implications for plant sciences', *New Phytologist*, 174: 279–297.

Jones, DR 2003, 'Revised datasheet of *Phytophthora ramorum*', CSL Forest Research.

Judelson, HS & Blanco, FA 2005, 'The spores of *Phytophthora*: Weapons of the plant destroyer', *Nature Reviews Microbiology*, 3: 47–58.

Jung, T 2009, 'Beech decline in Central Europe driven by the interaction between *Phytophthora* infections and climatic extremes', *Forest Pathology*, 39: 73–94.

Jung, T, Cooke, DEL, Blaschke, H, Duncan, JM & Osswald, W 1999, '*Phytophthora quercine* sp.*nov*, causing root rot of European oaks', *Mycologic*al *Research*, 103: 785–798.

Jung, T, Nechwatal, J, Cooke, DEL, Hartmann, G, Blaschke, M, Osswald, WF, Duncan, JM & Delatour, C 2003, '*Phytophthora pseudosyringae* sp. *nov*, a new species causing root and collar rot of deciduous tree species in Europe', *Mycologic*al *Research*, 107: 772–789.

Jung, T, Vannini, A & Brasier, CM 2007, 'Progress in understanding *Phytophthora* diseases of trees in Europe 2004–2007', In: '*Phytophthora*s in forests and natural ecosystems', *Proceedings of the Fourth Meeting of the International Union of Forest Research Organizations* (IUFRO) Working Party S07.02.09 August 26–31, 2007, Monterey, California, accessed Feburary 2013, fs.fed.us/psw/publications/documents/psw_gtr221/psw_gtr221.

Kelly, NM & Meentemeyer, R 2002, 'Landscape dynamics of the spread of sudden oak death', *Photogrammetric Engineering and Remote Sensing*, 68: 1001–1009.

Kliejunas, J 2000, 'Sudden oak death, *Phytophthora* sp., pest risk assessment', camfer.cnr.berkeley.edu/oaks/SODPRA.html.

Kliejunas, J 2003, 'A pest risk assessment of *Phytophthora ramorum* in North America', USDA Forest Service, suddenoakdeath.org/pdf/RevisedPRA.8.03.pdf.

Kliejunas, JT 2010, 'Sudden oak death and *Phytophthora ramorum*: a summary of the literature', USDA Forest Service, suddenoakdeath.org/wp-content/uploads/2010/03/psw_gtr234.pdf.

Kuljian, H & Varner, JM 2010, 'The effects of sudden oak death on foliar moisture content and crown fire potential in tanoak', *Forest Ecology and Management*, 259: 2103–2110.

Lane, CR, Beales, PA, Hughes, KJD, Tomlinson, JA, Inman, AJ & Warwick, K 2004, 'First report of ramorum dieback (*Phytophthora ramorum*) on container-grown English yew (*Taxus baccata*) in England', *Plant Pathology*, 53: 522.

Lane, CR, Hobben, E, Walker, L, Barton, VC, Inman, AJ, Hughes, KJD, Swan, H, Colyer, A & Barker, I 2007, 'Evaluation of a rapid diagnostic field test kit for identification of a *Phytophthora* species, including *P. ramorum* and *P. kernoviae* at the point of inspection', *Plant Pathology*, 56: 828–835.

Lewis, CD & Parke, JL 2006, 'Pathways of infection for *Phytophthora ramorum* in *Rhododendron*', *Proceedings of the Sudden Oak Death Second Science Symposium: The State of Our Knowledge*, General technical report PSW-GTR-196, 295–297.

Lilja, A, Rytkönen, A, Kokkola, M, Parikka, P & Hantula, J 2007, 'First report of *Phytophthora ramorum* and *P. inflata* in ornamental rhododendrons in Finland', *Disease Notes*, 91: 1055.

Linderman, RG & Davis, EA 2006a, 'Survival of *Phytophthora ramorum* compared to other species of *Phytophthora* in potting media components, compost, and soil', *HortTechnology*, 16: 502–507.

Linderman, RG & Davis, EA 2006b, 'Survival of *Phytophthora* species and other pathogens in soilless media components or soil and their eradication with aerated steam', *Proceedings of the Sudden Oak Death Second Science Symposium: The State of Our Knowledge,* General technical report PSW-GTR-196, 299–302.

Linzer, R, Rizzo, D & Garbelotto, M 2006, 'AFLP analysis of *Phytophthora nemorosa* and *P. pseudosyringae* genetic structure in North America', *Proceedings of the Sudden Oak Death Second Science Symposium: The State of Our Knowledge,* General technical report PSW-GTR-196.

Linzer, RE & Garbelotto, M 2008, 'Pathogenicity variation in two West Coast forest *Phytophthoras, Phytophthora nemorosa* and *P. pseudosyringae*, to bay laurel', *Proceedings of the Sudden Oak Death 3rd Science Symposium*, General Technical Report PSW-GTR-214, 19–26.

Linzer, RE, Rizzo, DM, Cacciola, SO & Garbelotto, M 2009, 'AFLPs detect low genetic diversity for *Phytophthora nemorosa* and *P. pseudosyringae* in the US and Europe', *Mycological Research*, 113: 298–307.

Maloney, PE, Lynch, SC, Kane, SF, Jensen, CE & Rizzo, DM 2005, 'Establishment of an emerging generalist pathogen in redwood forest communities', *Journal of Ecology*, 93: 899–905.

Maloney, PE, Rizzo, DM, Koike, ST, Harnik, TY & Garbelotto, M 2002, 'First report of *Phytophthora ramorum* on coast redwood in California', *Plant Disease* 86: 1274.

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 2008, 'Mitochondrial haplotype determination in the oomycete plant pathogen *Phytophthora ramorum*'. *Current Genetics* 54: 23–34.

Martin, FN, Abad, ZG, Balci, Y & Ivors, K 2012, 'Identification and detection of *Phytophthora*: reviewing our progress, identifying our needs', *Plant Disease*, 96: 1081–1103.

Martin, FN, Tooley, PW & Blomquist, C 2004, 'Molecular detection of *Phytophthora ramorum*, the causal agent of sudden oak death in California, and two additional species commonly recovered from diseased plant material', *Phytopathology*, 94: 621–631.

Mascheretti, S, Croucher, P, Kozanitas, M, Baker, L & Garbelotto, M 2009, 'Genetic epidemiology of the sudden oak death pathogen *Phytophthora ramorum* in California', *Molecular Ecology*, 18: 4577–4590.

Mascheretti, S, Croucher, P, Vettraino, A, 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.

Mathew, SK & Beena, S 2012, 'A new record of *Phytophthora ramorum* causing leaf fall and shoot rot of nutmeg (*Myristica fragrans*)', *Journal of Mycology and Plant Pathology*, 42: 529–530.

McGregor, BM 1987, 'Tropical products transport handbook', Agriculture Handbook No. 668. United States Department of Agriculture, Washington, DC.

Meshriy, M, Hüberli, D, Tamar, H, Miles, L, Reuther, K & Garbelotto, M 2006, 'Variation in susceptibility of *Umbellularia californica* (bay laurel) to *Phytophthora ramorum*', *Proceedings of the Sudden Oak Death Second Science Symposium: The State of Our Knowledge,* General technical report PSW-GTR-196, 87–89.

Metz, M, Frangioso, K, Meentemeyer, R & Rizzo, D 2011, 'Interacting disturbances: wildfire severity affected by stage of forest disease invasion', *Ecological Applications*, 21: 313–320.

Metz, M, Frangioso, K, Meentemeyer, R & Rizzo, DM 2010, 'Interacting disturbances: did sudden oak death mortality in Big Sur worsen the impacts of the 2008 Basin Complex wildfire?', *Proceedings of the 4th Sudden Oak Death Symposium*, 258–261.

Moralejo, E, Denman, S, Beales, P & Webber, J 2007, 'Report on the ability of key tree and nontree hosts to support inoculum production of *Phytophthora ramorum*', EU Sixth Framework Project RAPRA, Deliverable Report 27, rapra.csl.gov.uk.

Moralejo, E, García-Muñoz, JA & Descals, E 2008, 'Susceptibility of Iberian trees to *Phytophthora ramorum* and *P. cinnamomi*', *Plant Pathology*, 58: 271–283.

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.

Mostowfizadeh-Ghalamfarsa, R, Banihashemi, Z & Cooke, DEL 2008, '*Phytophthora parsiana* sp. *nov*., a new high-temperature tolerant species', *Mycological Research*, 112: 783 –794.

Murphy, SK & Rizzo, DM 2003 'First report of *Phytophthora ramorum* on canyon live oak in California', *Plant Disease*, 87: 315.

Murphy, SK & Rizzo, DM 2005, 'Incidence of *Phytophthora ramorum*, *P. nemorosa* and *P. pseudosyringae* in three coastal California forest communities', *Proceedings of the Second Sudden Oak Death Science Symposium*, General Technical Report PSW-197.

Murphy, SK & Rizzo, DM 2006, 'Incidence of *Phytophthora ramorum*, *P. nemorosa* and *P. pseudosyringae* in three coastal California forest communities', *Proceedings of the Sudden Oak Death Second Science Symposium: The State of Our Knowledge*, General technical report PSW-GTR-196, 69–71.

Murphy, SK, Bienapfl, J, Rizzo, DM, Valachovic, Y & Lee, C 2006, 'Monitoring *Phytophthora ramorum* distribution in streams within Coastal California watersheds' [Abstract], *Sudden Oak Death Second Science Symposium: The State of Our Knowledge*, 531.

Murphy, SK, Wickland, AC, Lynch, SC, Jensen, CE, Maloney, PE & Rizzo, DM 2008, 'Distribution of *Phytophthora ramorum*, *P. nemorosa* and *P. pseudosyringae* in Native Coastal California Forest Communities', *Proceedings of the Sudden Oak Death Third Science Symposium*, 51–54.

NAPPO (North American Plant Protection Organisation) 2003, '*NAPPO position on soil movement',* accessed June 2014, nappo.org/en/data/files/download/Positions percent20and percent20Decisions/PNo.1-Soil percent20Movement-e.pdf

NAPPO (North American Plant Protection Organisation) 2006, '*Phytophthora kernoviae* found for the first time in New Zealand', *Pest Alert*, pestalert.org.

Noble, R & Roberts, SJ 2004, 'Eradication of plant pathogens and nematodes during composting: a review', *Plant Pathology*, 53: 548–568.

Nogueira, MLB, de Silva, PP & Bartnicki-Garcia, S 1977, 'Membrane fusion during secretion: A hypothesis based on electron microscope observation of *Phytophthora palmivora* zoospores during encystment', *The Journal of Cell Biology*, 73: 161–181.

O'Gara, E, Huberli, D & Hardy, G 2005, '*Phytophthora ramorum*: a threat to Australia?', *Australasian Plant Conservation*, 13: 22–24.

Olejarski, I, Kubiak, K, Nowakowska, J, Jung, T & Oszako, T 2012, 'The occurrence of *Phytophthora* species in European Ecological Network NATURA 2000 in Poland', In: '*Phytophthora* in Forests and Natural Ecosystems', *The Sixth Meeting of the International Union of Forest Research Organizations IUFRO Working Party* [Meeting abstracts], Córdoba (Spain) September 2012, iufrophytophthora2012.org/downloads/IUFRO2012_BookofAbstracts.pdf accessed Feb 2012.

Orlikowski, LB & Szkuta, G 2004, 'First report of *Phytophthora ramorum* on *Calluna vulgaris, Photinia fraseri* and *Pieris japonica* in Polish container-ornamental nurseries', *Phytopathologia Polonica*, 34: 87–92.

Orlikowski, LB, Ptaszek, M, Orlikowska, T & Trzewik, T 2010, '*Phytophthora* species, new pathogens in landscape and gardens', *Botanikos Sodo Raštai*, 14: 133–138.

Osterbauer, NK 2004, '*Phytophthora ramorum Pest risk assessment for Oregon*', accessed December 2004, oda.state.or.us/plant/ppd/path/SOD/SOD_PRA_Oregon_2=03.pdf.

Parke, J, Oh, E, Voelker, S, Hansen, E, Buckles, G & Lachenbruch, B 2008, '*Phytophthora ramorum* infects Tanoak sapwood and is associated with reduced sap flux and specific conductivity of xylem', *Proceedings of the Sudden Oak Death Third Science Symposium*, fs.fed.us/psw/publications/documents/psw_gtr214/psw_gtr214_153_parke.pdf.

Parke, J, Pscheidt, J & Linderman, R 2004a, '*Phytophthora ramorum*: A guide for Washington nurseries', Oregon State University Extension Service, accessed March 2013, suddenoakdeath.org/.

Parke, JL & Lewis, C 2007, 'Root and stem infection of *Rhododendron* from potting medium infested with *Phytophthora ramorum*', *Plant Disease*, 91: 1265–1270.

Parke, JL & Lucas, S 2008, 'Sudden oak death and ramorum blight', The Plant Health Instructor, accessed May 2011, apsnet.org/edcenter/intropp/lessons/fungi/Oomycetes/Pages/SuddenOakDeath.aspx.

Parke, JL & Rizzo, DM 2011, '*Phytophthora ramorum*', *Forest Phytophthoras*, 1, doi: 10.5399/osu/fp.1.1.1821.

Parke, JL, Hansen, E, Buckles, G, Voelker, S, Collins, B & Lachenbruch, B 2007a, '*Phytophthora ramorum* infects sapwood and is associated with reduced specific conductivity of xylem vessels in tanoak', *Sudden Oak Death Symposium III*.

Parke, JL, Hansen, EM & Linderman, RG 2002a, 'Sporulation potential of *Phytophthora ramorum* on leaf disks from selected hosts' [Abstract], *Proceedings of the Sudden Oak Death, A Science Symposium*, 33.

Parke, JL, Linderman, RG, Osterbauer, NK & Griesbach, JA 2004b, 'Detection of *Phytophthora ramorum* blight in Oregon nurseries and completion of Koch's postulates on *Pieris*, *Rhododendron*, *Viburnum* and *Camellia*', *Plant Disease*, 88: 87.

Parke, JL, Linderman, RJ, Hummer, K & Hansen, EM 2002b, 'Assessing the susceptibility of Pacific Northwest nursery plants to *Phytophthora ramorum* using a detached leaf assay' [Abstract], *Proceedings of the Sudden Oak Death, A Science Symposium*, 84–85.

Parke, JL, Linderman, RJ, Hummer, K & Hansen, EM 2002c, 'Differential susceptibility to *Phytophthora ramorum* among *Vaccinium* species and cultivars' [Abstract], *Proceedings of the Sudden Oak Death, A Science Symposium*, 83–84.

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

Pintos Varela, C, Mansilla Vázquez, JP & Aguín Casal, O 2003, 'First Report of *Phytophthora ramorum* on *Camellia japonica* in Spain', *Plant Disease*, 87: 1396.

Pogoda, F & Werres, S 2004, 'Histological studies of *Phytophthora ramorum* in *Rhododendron* twigs', *Canadian Journal of Botany*, 82: 1481–1489.

Prospero, S, Grünwald, NJ, Winton, LM & Hansen, EM 2009, 'Migration patterns of the emerging plant pathogen *Phytophthora ramorum* on the West Coast of the United States of America', *Phytopathology*, 99: 739–749.

Prospero, S, Hansen, EM, Grünwald, NJ & Winton, LM 2007, 'Population dynamics of the sudden oak death pathogen *Phytophthora ramorum* in Oregon from 2001 to 2004', *Molecular Ecology*, 16: 2958–2973.

Purse, BV, Graeser, P, Searle, K, Edwards, C & Harris, C 2013, 'Challenges in predicting invasive reservoir hosts of emerging pathogens: mapping *Rhododendron ponticum* as a foliar host for *Phytophthora ramorum* and *Phytophthora kernoviae* in the UK', *Biological Invasions*, 15: 529–545.

Ramsfield, TD, Dick, MA, Beever, RE & Horner, IJ 2007, '*Phytophthora kernoviae* – of southern hemisphere origin?', *4th IUFRO Phytophthoras in Forests & Natural Ecosystems*.

Ramsfield, TD, Dick, MA, Beever, RE, Horner, IJ, McAlonan, MJ & Hill, CF 2009, '*Phytophthora kernoviae* in New Zealand', *Proceedings of the 4th meeting of the International Union of Forest*

Research Organizations (IUFRO), Working Party S07.02.09, General technical report PSW-GTR-221, 47–53.

Randall, RP 2007, '*The introduced flora of Australia and its weed status*', CRC for Australian Weed Management, Department of Agriculture and Food, Western Australia.

RAPRA Database 2012, rapra.csl.gov.uk/ Online version of: Sansford, CE, Inman, AJ, Baker, R, Brasier, C, Frankel, S, de Gruyter, J, Husson, C, Kehlenbeck, H, Kessel, G, Moralejo, E, Steeghs, M, Webber, J & Werres, S 2008, '*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*', Deliverable Report 28, EU Sixth Framework Project RAPRA.

Reeser, P, Sutton, W, Hansen, EM, Remigi, P & Adams, GC 2011, '*Phytophthora* species in forest streams in Oregon and Alaska', *Mycologia*, 103: 22–35.

Riedel, M, Werres, S, Elliott, E, McKeever, K & Shamoun, SF 2012, 'Histopathological investigations of the infection process and propagule development of *Phytophthora ramorum* on rhododendron leaves', Forest Phytophthoras vol. 2, issue 1. doi: 10.5399/osu/fp.2.1.3036.

Riedel, M, Calmin, G, Belbahri, L, Lefort, F, Goetz, M, Wagner, S & Werres, S 2009, 'Green Fluorescent Protein (GFP) as a reporter gene for the plant pathogenic oomycete *Phytophthora ramorum*', *Journal of Eukaryotic Microbiology*, 56: 130–135.

Riley, KL & Chastagner, GA 2011, 'First report of *Phytophthora ramorum* infecting mistletoe in California', *Plant Health Progress*, doi: 10.1094/PHP-2011-0209-02-BF.

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

Ristaino, JB & Gumpertz, ML 2000, 'New frontiers in the study of dispersal and spatial analysis of epidemics caused by species in the genus *Phytophthora*', *Annual Review of Phytopathology*, 38: 541–576.

Rizzo, DM & Garbelotto, M 2003, 'Sudden oak death: endangering California and Oregon forest ecosystems', *Frontiers in Ecology and the Environment*, 5: 197–204.

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

Rizzo, DM, Garbelotto, M, Davidson, JM, Slaughter, GW & Koike, ST 2002a, '*Phytophthora ramorum* and Sudden Oak Death in California: I. Host Relationships', *Proceedings of the 5th Symposium on California Oak Woodlands*, General technical report PSW-GTR-184, 733–740.

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

Rooney-Latham, S, Honeycutt, E, Ochoa, J, Grünwald, NJ & Blomquist, CL 2013, 'First report of Camphor Tree (*Cinnamomum camphora*) as a host plant of *Phytophthora ramorum*', *Plant Disease*, 97: 1377.

Rytkönen, A, Lilja, A, Parikka, P, Hannukkala, A, Kokkola, M & Hantula, J 2007, '*Phytophthora* species', In: '*Phytophthora*s in Forests and Natural Ecosystems', *Finlandin Meeting Abstracts of the Fourth International IUFRO Working Party*, 62.

Sansford, C 2012, 'Revised Rapid Assessment of the need for a detailed Pest Risk Analysis for *Phytophthora pseudosyringae*', Food and Environment Research Agency (FERA), fera.defra.gov.uk/plants/plantHealth/pestsDiseases/documents/phytophthoraPseudosyringae0312.pdf, Accessed March 2014.

Sansford, CE 2008, 'Revised summary pest risk analysis for *Phytophthora kernoviae*', CSL Forest Research, fera.defra.gov.uk/plants/plantHealth/pestsDiseases/documents/pker.pdf.

Sansford, CE, Inman, AJ, Baker, R, Brasier, C, Frankel, S, de Gruyter, J, Husson, C, Kehlenbeck, H, Kessel, G, Moralejo, E, Steeghs, M, Webber, J & Werres, S 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, rapra.csl.gov.uk/.

Savidor, A, Ryan, S, Donahoo, RS, Hurtado-Gonzales, O, Land, ML, Shah, MB, Lamour, KH & McDonald, WH 2008, 'Cross-species global proteomics reveals conserved and unique processes in *Phytophthora sojae* and *Phytophthora ramorum*', *Molecular & Cellular Proteomics*, 7.8: 1501–1516.

Scanu, B, Jones, B & Webber, JF 2012, 'A new disease of *Nothofagus* in Britain caused by *Phytophthora pseudosyringae*', *New Disease Reports*, 25: 27.

Scanu, B, Linaldeddu, BT & Franceschini, A 2010, 'First report of *Phytophthora pseudosyringae* associated with ink disease of *Castanea sativa* in Italy', *Plant Disease*, 94: 1068.

Schwingle, BW & Blanchette, RA 2008, 'Host range investigations of new, undescribed, and common *Phytophthora* species isolated from ornamental nurseries in Minnesota', *Plant Disease*, 92: 642–647.

Schwingle, BW, Smith, JA & Blanchette, RA 2007, '*Phytophthora* species associated with diseased woody ornamentals in Minnesota nurseries', *Plant Disease*, 91: 97–102.

Schwingle, BW, Smith, JA, Blanchette, RA, Gould, S, Blanchette, BL, Pokorny, J & Cohen, SD 2006, 'First report of dieback and leaf lesions on *Rhododendron* sp. caused by *Phytophthora hedraiandra* in the United States', *Plant Disease*, 90; 109.

Scianna, JD, Knudson, MK & Dickerson, JA 2003, '*Sudden Oak Death (SOD)*', USDA Natural Resourcs Conservation Services, *Plant Materials Technic*al *Note No. MT-44*, ftp-fc.sc.egov.usda.gov/MT/www/technical/plants/technotes/pmtechnoteMT44.pdf.

Shishkoff, N (2007) 'Persistence of *Phytophthora ramorum* in soil mix and roots of nursery ornamentals', *Plant Disease*, 91: 1245–1249.

Shurtleff, MC & Averre, CW 1997, '*Glossary of Plant-Pathological Terms*', American Phytopathology Society Press, St. Paul, MN.

Stenlid, J, Oliva, J, Boberg, JB & Hopkins, AJM 2011, 'Emerging diseases in European forest ecosystems and responses in society', *Forests*, 2: 486–504.

Sundheim, L, Herrero, ML, Rafoss, T & Toppe, B 2009, 'Pest risk assessment of *Phytophthora ramorum* in Norway', *Opinion of the Panel on Plant Health of the Norwegian Scientific Committee for Food Safety*, ISBN 978-82-8082-351-9.

Sutton, W, Hansen EM, Reeser PW, Kanaskie, A 2009, 'Stream monitoring for detection of *Phytophthora ramorum* in Oregon tanoak forests', *Plant Disease*, 93: 1182–1186.

Swain, S, Harnik, T, Mejia-Chang, M, Hayden, K, Bakx, W, Creque, J & Garbelotto, M 2006, 'Composting is an effective treatment option for sanitization of *Phytophthora ramorum*-infected plant material', *Journal of Applied Microbiology*, 101: 815–827.

Swain, S, Harnik, T, Mejia-Chang, M, Hayden, K, Creque, J & Garbelotto, M 2002, 'Survivability of *Phytophthora ramorum* in the composting process' [Abstract], *Proceedings of Sudden Oak Death, A Science Symposium*, 44.

Swiecki, TJ & Bernhardt, E 2002b, 'Evaluation of stem water potential and other tree and stand variables as risk factors for *Phytophthora ramorum* canker development in coast live oak', *Fifth Symposium on California OakWoodlands,* General technical report PSW-GTR-184, 787–798.

Swiecki, TJ & Bernhardt, E 2010, 'Long-term trends in coast live oak and tanoak stands affected by *Phytophthora ramorum* canker (sudden oak death)', *Sudden Oak Death Fourth Science Symposium*, 207–209.

Swiecki, TJ & Bernhardt, EA 2002a, 'Factors related to *Phytophthora* canker (sudden oak death) disease risk and disease progress in coast live oak and tanoak', Report for USDA Forest Service, Phytosphere Research Project No. 2001-0802.

Talgø, V, Herrero, ML, Brurberg, MB & Stensvand, A 2012, '*Phytophthora*–baiting in Norwegian waterways'[Meeting abstract], In: '*Phytophthora* in Forests and Natural Ecosystems', *The Sixth Meeting of the International Union of Forest Research Organizations IUFRO Working Party*, iufrophytophthora2012.org/downloads/IUFRO2012_BookofAbstracts.pdf

Theman, K, Werres, S, Lüttmann, R & Diener, HA 2002, 'Observations of *Phytophthora* species in water recirculation systems in commercial hardy ornamental nursery stock', *European Journal of Plant Pathology*, 108, 337–343.

Tjosvold, SA, Buermeyer, KR, Blomquist, C & Frankel, S 2005, 'Nursery guide for diseases caused by *Phytophthora ramorum* on ornamentals: diagnosis and management', *Agriculture and Natural Resources, Publication*, 8156.

Tjosvold, SA, Chambers, DL, Davidson, JM & Rizzo, DM 2002, 'Incidence of *Phytophthora ramorum* inoculum found in soil collected from a hiking trail and hikers' shoes in a California Park' [Abstract], *Proceedings of Sudden Oak Death, A Science Symposium*, 53.

Tjosvold, SA, Chambers, DL, Fichtner, EJ, Koike, ST & Mori, SR 2009, 'Disease risk of potting media infested with *Phytophthora ramorum* under nursery conditions', *Phytopathology*, 93: 371–376.

Tjosvold, SA, Koike, ST & Chambers, DL 2008, 'Evaluation of fungicides for the control of *Phytophthora ramorum* infecting *Rhododendron*, *Camellia*, *Pieris*, and *Viburnum*', *Plant Health Progress* 13, accessed May 2013, cesantacruz.ucdavis.edu/files/51742.pdf.

Tooley, PW, Browning, M & Berner, D 2008, 'Recovery of *Phytophthora ramorum* following exposure to temperature extremes', *Plant Disease*, 92: 431–437.

Tooley, PW, Kyde, KL & Englander, L 2004, 'Susceptibility of selected ericaceous ornamental host species to *Phytophthora ramorum*', *Plant Disease*, 88: 993–999.

Tsopelas, P, Paplomatas, E, Tjamos, S, Soulioti, N & Kalomoira, E 2011, 'First report of *Phytophthora ramorum* on *Rhododendron* in Greece', *Plant Disease*, 95: 223.

Turner, J, Jennings, P, & Humphries, G 2005, '*Phytophthora ramorum* epidemiology: sporulation potential, dispersal, infection, latency and survival', Department for Environment, Food and Rural Affairs (DEFRA) Project Report PH0194, randd.defra.gov.uk/Document.aspx.

Turner, JA & Jennings, P 2008, *Report indicating the limiting and optimal environmental conditions for production, germination and survival of sporangia and zoospores*, Deliverable Report 7. Sand Hutton, York, UK: Forest Research.

Turner, JA, Jennings, P & Humphries 2006, '*P. ramorum/P. kernoviae*: Development of post-eradication strategies for management/treatment of contaminated substrates and inoculum at outbreak sites', *Internal quarterly reports 1, 2 and 3*, DEFRA Project number PH0414.

Varela, CP, Vazquez, JPM, Casal, OA & Martinez, CR 2007, 'First report of *Phytophthora pseudosyringae* on chestnut nursery stock in Spain', *Plant Disease* 91: 1517.

Vettraino, AM, Sukno, S, Vannini, A & Garbelotto, M 2010, 'Diagnostic sensitivity and specificity of different methods used by two laboratories for the detection of *Phytophthora ramorum* on multiple natural hosts', *Plant Pathology*, vol. 59, no. 2, pp. 289–300.

Vettraino, AM, Ceccarelli, B & Vannini, A 2009, 'Susceptibility of some Italian ornamental and forestry species to *Phytophthora ramorum*,' In: '*Phytophthora*s in Forests and Natural Ecosystems', *Proceedings of the 4th Meeting of IUFRO Working Party* S07.02.09, PSW-GTR-221: 137–139.

Vettraino, AM, Hüberli, D & Garbelotto, M 2008, '*Phytophthora ramorum* infection of coast live oak leaves in Californian forests and its capacity to sporulate in vitro', *Australasian Plant Pathology*, 37: 72–73.

Vettraino, AM, Hüberli, D, Swain, S, Bienapfl, JC, Smith, A & Garbelotto, M 2006a, 'First report of infection of Maiden-Hair Fern (*Adiantum jordanii* and *A. aleuticum*) by *Phytophthora ramorum* in California', *Plant Disease*, 90: 379.

Vettraino, AM, Hüberli, D, Swain, S, Smith, A & Garbelotto, M 2006b, 'A new report of *Phytophthora ramorum* on *Rhamnus purshiana* in Northern California', *Plant Disease*, 90: 246.

Waterhouse, GM 1963, '*Key to the species of Phytophthora*', Commonwealth Mycological Institute Kew, UK, 92.

Webber, J 2010, 'Pest risk analysis and invasion pathways for plant pathogens', *New Zealand Journal of Forestry Science*, 40: 45–55.

Webber, JF & Rose, J 2007, 'Dissemination of aerial and root infecting *Phytophthora*s by human vectors' [Abstract], *Proceedings of the Sudden Oak Death Symposium III*, 88: 275–278.

Webber, JF 2008, 'Status of *Phytophthora ramorum* and *P. kernoviae* in Europe', *Proceedings of the Sudden Oak Death 3rd Science Symposium*, General technical report PSW-GTR-214, 19–26.

Webber, JF, Mullett, M & Brasier, CM 2010a, 'Dieback and mortality of plantation Japanese larch (*Larix kaempferi*) associated with infection by *Phytophthora ramorum*', *New Disease Reports*, 22: 19.

Webber, JF, Turner, J & Jennings, P 2010b, 'Report on research undertaken between October 2009 to March 2010, on *Phytophthora ramorum* incited dieback of larch (*Larix kaempferi*)', Forest Research (UK) Report, accessed November 2013, fera.defra.gov.uk/plants/plantHealth /pestsDiseases/phytophthora/documents/larchReport.pdf.

Werres, S & De Merlier, D 2003, 'First detection of *Phytophthora ramorum* mating type A2 in Europe', *Plant Disease*, 87: 1266.

Werres, S & Kaminski, K 2005, 'Characterisation of European and North American *Phytophthora ramorum* isolates due to their morphology and mating behaviour in vitro with heterothallic *Phytophthora* species', *Mycological Research*, 109: 860–871.

Werres, S & Zielke, B 2003, 'First studies on the pairing of *Phytophthora ramorum*', *Journal of Plant Disease and Protection*, 110: 129–130.

Werres, S, Marwitz, R, Man In'T Veld, WA, De Cock, AWAM, Bonants, PJM, De Weerdt, M, Themann, K, Ilieva, E & Baayen, RP 2001, '*Phytophthora ramorum* sp. *nov*., a new pathogen on *Rhododendron* and *Viburnum*', *Mycological Research*, 105: 1155–1165.

Weste, G & Marks, GC 1987, 'The biology of *Phytophthora cinnamomi* in Australasian forests', *Annual Review of Phytopathology*, 25: 207–229.

Wickland, AC & Rizzo, DM 2006, 'Ecology of *Phytophthora nemorosa* and *P. pseudosyringae* in mixed evergreen forests', *Proceedings of the Sudden Oak Death Second Science Symposium: The State of Our Knowledge*, General Technical Report PSW-GTR-196, 73.

Wickland, AC, Jensen, CE & Rizzo, DM 2008, 'Geographic distribution, disease symptoms and pathogenicity of *Phytophthora nemorosa* and *P. pseudosyringae* in California, USA', *Forest Pathology*, 38: 288–298.

Widmer, T 2011, 'Effect of temperature on survival of *Phytophthora kernoviae* oospores, sporangia, and mycelium', *New Zealand Journal of Forestry Science*, 41S: S15–S23, scionresearch.com/nzjfs.

Widmer, TL 2010, '*Phytophthora kernoviae* oospore maturity, germination and infection', *Fungal Biology*, 114: 661–668.

Wingfield, MJ, Slippers, B & Wingfield, BD 2010, 'Novel associations between pathogens, insects and tree species threaten world forests', *New Zealand Journal of Forestry Science*, 40: 95–103.

Wong, K 2008, 'Canadian *Phytophthora ramorum* 2006 Update', *Proceedings of the Sudden Oak Death Third Science Symposium*, General technical Report PSW-GTR-214, 35–36.

WTO (World Trade Organisation) 1995, 'Agreement on Sanitary and Phytosanitary Measures', wto.org/english/res_e/booksp_e/analytic_index_e/sps_01_e.htm#pA.

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.