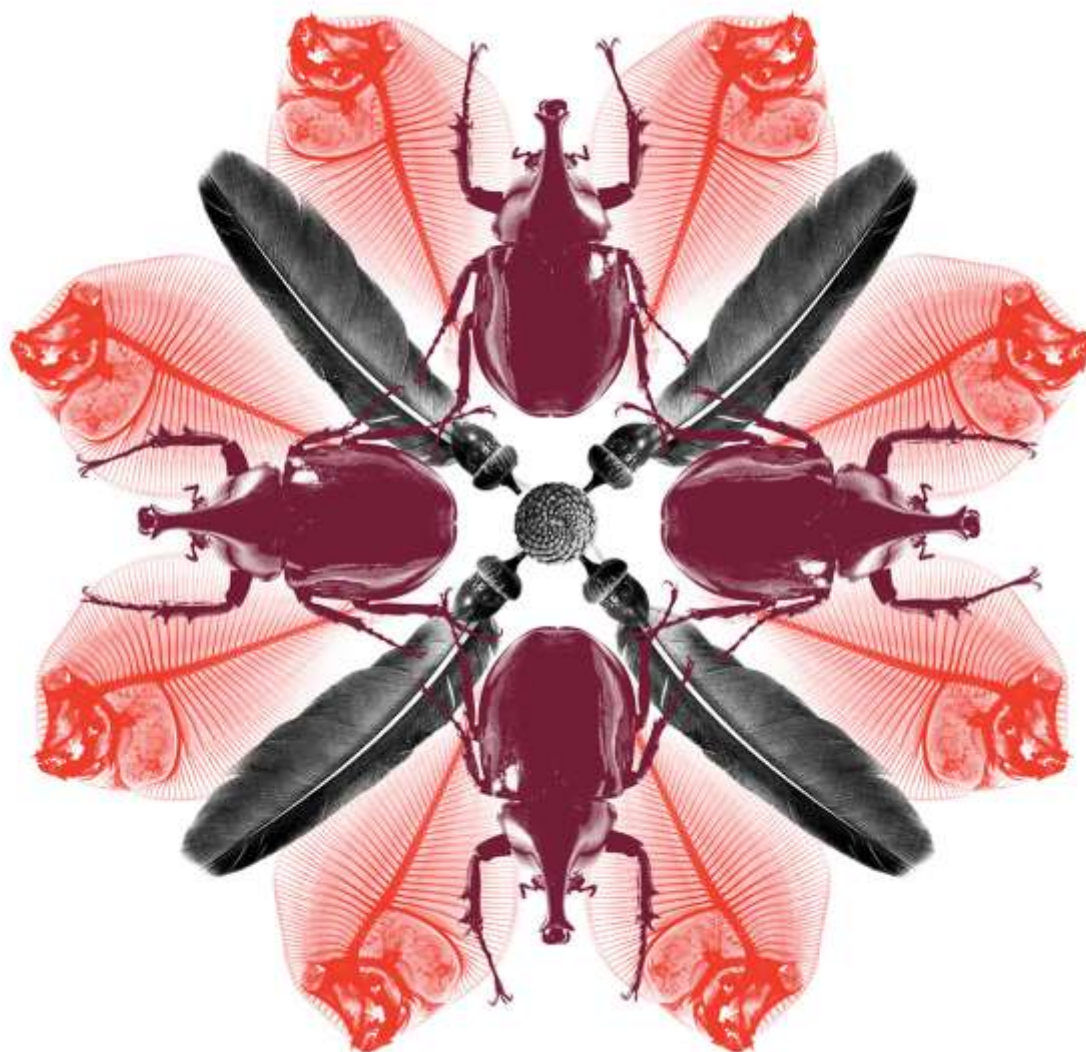




Australian Government
Department of Agriculture

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

March 2015



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Submissions

This draft report has been issued to give all interested parties an opportunity to comment and draw attention to any scientific, technical, or other gaps in the data, misinterpretations and errors. Any comments should be submitted to the Australian Department of Agriculture within the comment period stated in the related Biosecurity Advice on the website. The draft report will then be revised as necessary to take account of the comments received and a final report prepared.

Comments on the draft report should be submitted to:

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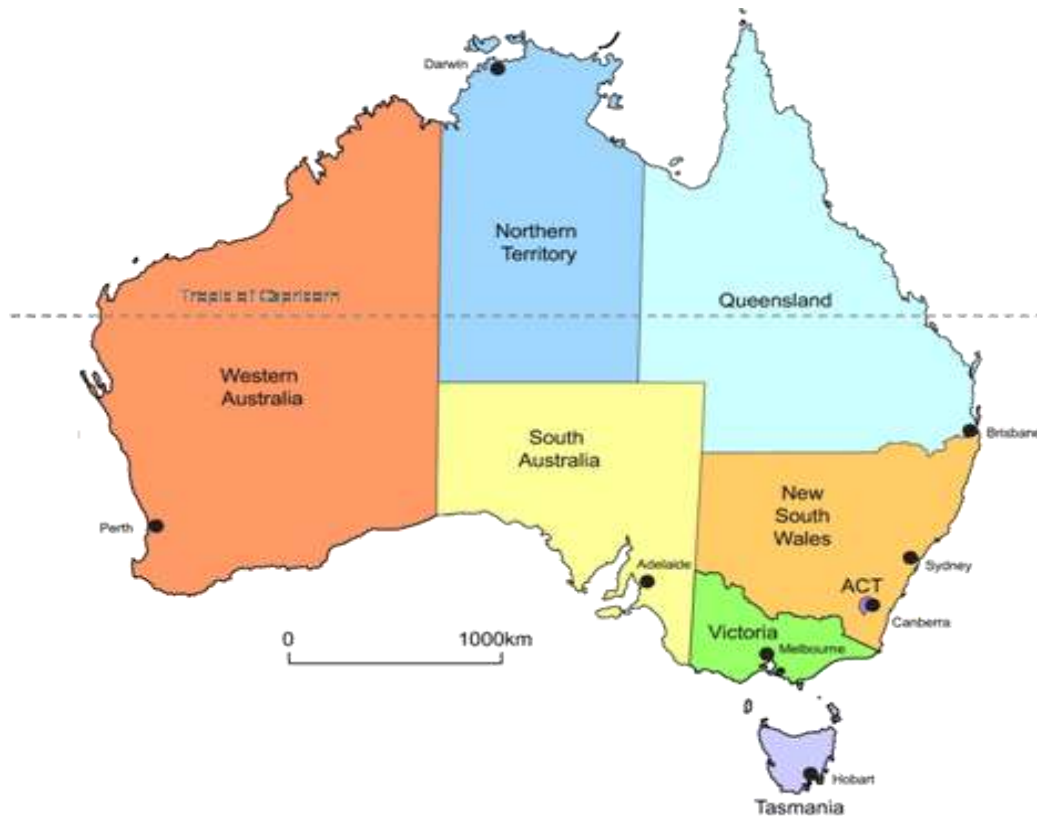
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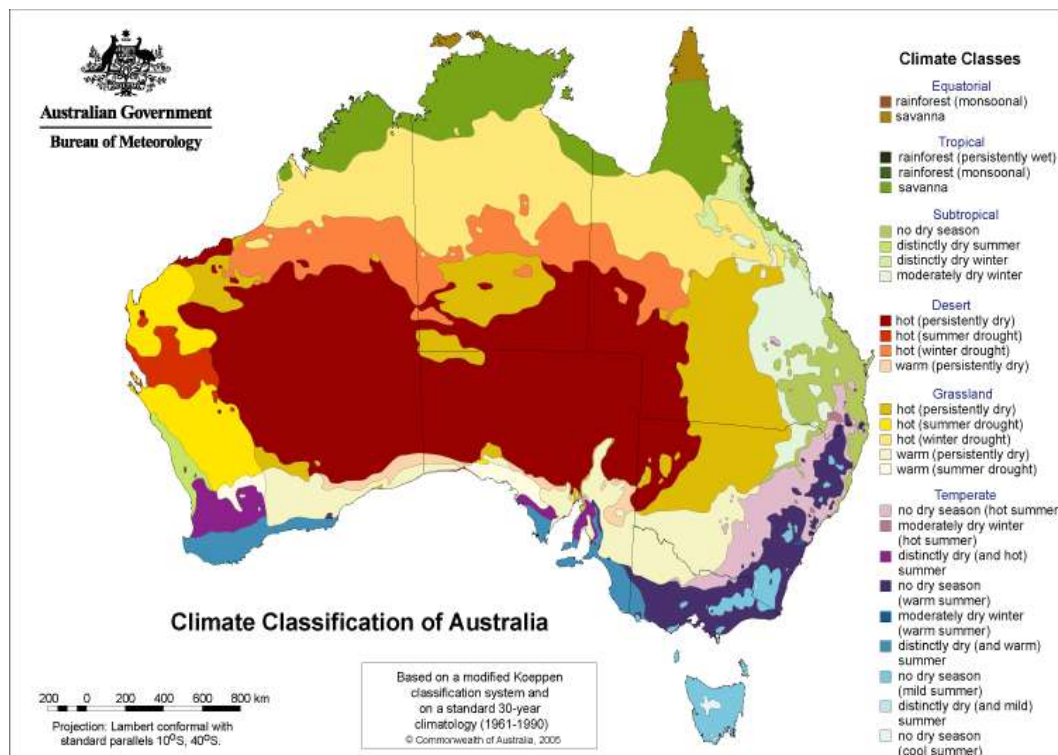
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Map 1 Map of Australia



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 Import CONditions database
IPC	International Phytosanitary Certificate
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
PEQ	Post-entry quarantine
PCR	Polymerase Chain Reaction
PRA	Pest risk assessment
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 initiated this review following a request from the Australian nursery industry to revise the import conditions for nursery stock from countries where *Phytophthora ramorum* is known to occur. Surveys conducted overseas in response to *P. ramorum* outbreaks identified several new species of *Phytophthora* including *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae*. These *Phytophthora* species share a similar host range, geographic range and cause symptoms indistinguishable from those of *Phytophthora ramorum*. This review therefore considers not only *Phytophthora ramorum* but also *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae*.

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.

The findings of this draft review of policy are based on a comprehensive analysis of the scientific literature. Based on this review the Department of Agriculture has proposed several changes to the existing policy. This review proposes:

- Updating the host list for *Phytophthora ramorum* and including hosts of *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae*.
- Reducing the post-entry quarantine (PEQ) growth period for dormant hardwood cuttings and budwood from 24 months to 15 months with visual screening, culturing and active testing for all four *Phytophthora* species using molecular techniques including but not limited to polymerase chain reaction (PCR).
- Allowing the importation of one-year-old, bare-rooted plants without foliage. On arrival, the bare-rooted plants will be subjected to inspection, fumigation, culturing and molecular testing (generic *Phytophthora* PCR) to screen for *Phytophthora* species, and sodium hypochlorite treatment. This will be followed by 15 months growth in PEQ with visual inspection and molecular testing including, but not limited to, PCR.

The existing conditions for propagative material from countries where these *Phytophthora* species are not known to occur are proposed to continue. The ultimate goal of Australia's phytosanitary measures is to protect plant health and prevent the introduction of identified quarantine pests and pathogens associated with plant propagative material. The department considers that the risk management measures proposed in this draft review of policy will be adequate to mitigate the risks posed by the *Phytophthora* species under review.

In the interim, some of the proposed changes in this document have been adopted and the Department of Agriculture's Import CONditions database (ICON) has been updated accordingly. Industry was notified through an ICON alert.

The Department of Agriculture invites comments on the technical aspects of the proposed risk management measures within the consultation period. In particular, comments are sought on their appropriateness and any other measures stakeholders consider would provide equivalent risk management outcomes. The Department of Agriculture will consider any comments received before finalising the pest risk analysis and quarantine policy recommendations.

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 conservative, 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, 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.

The department's assessment may take the form of an import risk analysis (IRA), a non-regulated analysis of existing policy, or technical advice.

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](#) 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 allowed only 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* 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 culture 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 culture, 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 this review, it was determined that dormant unrooted 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* (Schwingle et al. 2006; Martin & Tooley 2003; Webber 2008; Wickland et al. 2008; Fichtner et al. 2011). These *Phytophthora* species share a similar host range and geographic range with *P. ramorum* (Webber 2008; Martin et al. 2004; Linzer & Garbelotto 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 will also consider the newly identified *Phytophthora* species, including *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae*, which share hosts with *P. ramorum*.

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 *Phytophthora kernoviae*, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum*; and
- the development of phytosanitary measures to import host material of *Phytophthora 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 analysis.

This draft review of policy is limited to proposing 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 Australian Customs Service, Department of Health and Ageing, Therapeutic Goods Administration, Australian Pesticides and Veterinary Medicines Authority, Department of the Environment and State Departments of Agriculture.

1.2.3 Existing policy

Currently, there are two separate sets of conditions that apply to propagative material of hosts of *Phytophthora ramorum*: those for sourcing propagative material from countries where this fungus is known to occur (European Union, North America) and those for sourcing propagative material from countries free from *P. ramorum*. These conditions are available on the department's Import CONditions database (ICON) at <http://www.agriculture.gov.au/icon>.

Propagative material from *Phytophthora ramorum* countries

The importation of all rooted plant hosts of *Phytophthora ramorum* is prohibited from all countries where this pathogen is known to occur. The import conditions for tissue cultures from countries where *P. ramorum* is known to occur include:

- an import permit and Phytosanitary Certificate;
- mandatory on-arrival inspection to verify freedom from any bacterial or fungal infection, live insects, disease symptoms or other extraneous contamination of quarantine concern;
- mandatory growth under closed quarantine at a government post-entry quarantine facility for pathogen screening; and
- drenching prior to release from PEQ.

In 2013, following a request from industry, the department revised the import conditions for a limited number of genera that cannot be easily tissue cultured (Table 1). **Table 1 *Phytophthora* hosts currently permitted entry as dormant unrooted cuttings and budwood into Australia**

Scientific name	Common name
<i>Acer</i> [Aceraceae]	Maple
<i>Betula</i> [Betulaceae]	Birch
<i>Cercis</i> [Fabaceae]	Redbud
<i>Cornus</i> [Cornaceae]	Cornus
<i>Distylium</i> [Hamelidaceae]	Distylium
<i>Fraxinus</i> [Oleaceae]	Oregon ash
<i>Liriodendron</i> [Magnoliaceae]	Poplar
<i>Loropetalum</i> [Hamamelidaceae]	Fringe Flower
<i>Physocarpus</i> [Rosaceae]	Ninebark
<i>Syringa</i> [Oleaceae]	Lilac
<i>Ulmus</i> [Ulmaceae]	Elms

Following the finalisation of the 2013 review, it was determined that dormant unrooted cuttings and budwood of a limited number of genera could be imported from countries where *P. ramorum* is known to occur, subject to the following import conditions:

- an import permit and Phytosanitary Certificate;
- only dormant and unrooted cuttings or budwood are permitted;

- mandatory on-arrival inspection to verify freedom from bacterial and fungal infection, disease symptoms, live insects and other extraneous contamination of quarantine concern;
- mandatory fumigation with methyl bromide and sodium hypochlorite treatment;
- growth in closed quarantine at a government post-entry quarantine facility for a minimum of two years with disease screening for *Phytophthora* using PCR and visual inspections;
- imported material to be reworked, when sufficient new growth available, onto local rootstock plants propagated from Australian high-health (for example, virus tested) rootstocks supplied by the importer; and
- drenching of plants with a systemic fungicide prior to release from PEQ.

Propagative material from non *Phytophthora ramorum* countries

Import conditions for propagative material of hosts of *Phytophthora ramorum* from countries where the pathogen is not known to occur include:

- an import permit and a Phytosanitary Certificate with an additional declaration 'Sudden oak death (*Phytophthora ramorum*) is not known to occur in [insert country of origin]'; and
- conditions as detailed on ICON.

2 Method for pest risk analysis

This chapter sets out the method used for the pest risk analysis (PRA) in this report. The Department of Agriculture has conducted this PRA in accordance with the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: *Framework for pest risk analysis* (2007) and ISPM 11: *Pest risk analysis for quarantine pests* (2013b) 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 2013a). 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 risk analysis identifies pest(s) and pathway(s) that should be considered for risk analysis in relation to the identified PRA area.

This pest risk assessment was initiated as a basis for a review and possible revision of the current phytosanitary regulations to import hosts of *Phytophthora 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 will take 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 ornamental plants and propagative material, cuttings, bare-rooted plants) is a potential import 'pathway' by which these *Phytophthora* species could enter Australia.

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.

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 of the magnitude of the associated potential economic consequences' (FAO 2013a). 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:

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 2013a).

The process of a pest categorisation is summarised by ISPM 11 (FAO 2013b) 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
- 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 2013b). 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 distribution in the PRA area.

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

- **Probability of importation:** the probability that a pest will arrive in Australia when a given commodity is imported.
- **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 part of a 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
- 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)
- 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 2013a). 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
- 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 2013a). 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 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
- potential vectors of the pest in the PRA area.

Assigning qualitative likelihoods for entry, establishment and spread

In its qualitative PRAs, the Department of Agriculture 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 2). Descriptive definitions for these descriptors and their indicative probability ranges are given in Table 2. 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 2 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 3). 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 3 Matrix of rules for combining qualitative likelihoods

	High	Moderate	Low	Very low	Extremely low	Negligible
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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 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 of Agriculture normally considers the likelihood of entry on the basis of the estimated volume of one year's trade. However, in case of a high risk commodity the volume of trade is restricted to certain numbers. Therefore, other factors listed in ISMP 11 (FAO 2013b) 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 potential consequences are given in Article 5.3 of the SPS Agreement (WTO 1995), ISPM 5 (FAO 2013a) and ISPM 11 (FAO 2013b).

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

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

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

- eradication, control, etc.
- domestic trade

- international trade
- 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 and territories and Tasmania).

For each criterion, the magnitude of the potential consequence 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–G) using Table 4. For example, a consequence with a magnitude of ‘significant’ at the ‘district’ level will have a consequence impact score of D.

Table 4 Decision rules for determining the consequence impact score based on the magnitude of consequences at four geographic scales

Magnitude	Geographic scale			
	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 5 were adjusted accordingly. The decision rules for determining the consequence impact score are presented in a simpler form in Table 4 from earlier IRAs, 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 5). These rules are mutually exclusive, and are assessed in numerical order until one applies.

Table 5 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 6) 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 6 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 the 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 6 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 *Phytophthora* species being well known pathogens of agriculture, nursery and forestry industries (Birch & Whisson 2001; Erwin & Ribeiro 1996; Orlikowski et al. 2010; Weste & Marks 1987). 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 forests in Europe and the United States of America (USA) (Theman et al. 2002; Jung et al. 2003; Hansen et al. 2003a; Blomquist et al. 2005; Donahoo et al. 2006; Hong et al. 2008; Schwingle et al. 2006; 2007; Schwingle & Blanchette 2008; Moralejo et al. 2008; Yakabe et al. 2009; Grünwald et al. 2011).

Phytophthora ramorum was first described as a new *Phytophthora* species on *Rhododendron* and *Viburnum* 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 (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 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 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 (Blanco & Judelson 2005; Nogueira et al. 1977). 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 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 7.

Table 7 Characteristics of the *Phytophthora* species under review

	<i>Phytophthora</i> species			
	<i>P. kernoviae</i>	<i>P. nemorosa</i>	<i>P. pseudosyringae</i>	<i>P. ramorum</i>
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
Host	Multiple	Multiple	Multiple	Multiple
Infected tissues	Stem/foilage	Stem/foilage	Foliage	Stem/foilage
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).

There are also several critical differences between the *Phytophthora* species considered in this review. Not least, the pathogens have different breeding systems: *P. ramorum* is heterothallic (Werres et al. 2001) whereas *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae* are homothallic (Brasier et al. 2005).

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 degrees Celsius. 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 the Western USA, sexual reproduction has to date not been found (Kliejunas 2010; Goss et al. 2011; Grünwald et al. 2012).

Phytophthora kernoviae is not known to produce 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 degrees Celsius and 26 degrees Celsius (Brasier et al. 2005), which indicates that *P. kernoviae* may be adapted to a temperate climate. Oospores of *Phytophthora kernoviae* can survive for long periods at temperatures of 30 degrees Celsius 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 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 degrees Celsius) than *P. ramorum* (20 degrees Celsius) (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).

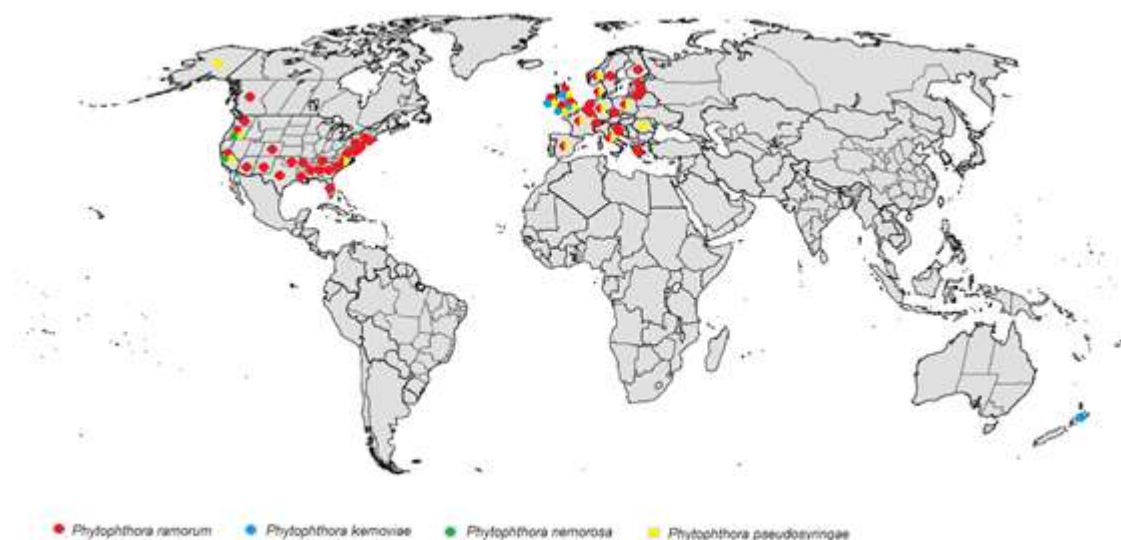
3.3 Global occurrence of the *Phytophthora* species

Phytophthora ramorum was first reported to be associated with twig blight disease on *Rhododendron* and *Viburnum* in Germany and the Netherlands (Werres et al. 2001) and on *Quercus* species 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 (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 as *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* is a host of several *Phytophthora* species and has 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* is 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* in California (Kelly & Meentemeyer 2002; Meshriy et al. 2006; Swiecki & Bernhardt 2002a, b).
- **Magnoliaceae** includes ornamental and forest plants; for example, *Manglietia insignis*, *Magnolia* species, *Michelia* species and *Parakilometerseria 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 plants (*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, maidenhair ferns) and ornamentals (*Rhododendron* species, *Camellia* species, *Viburnum* species, *Pieris* species, 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); therefore, water is a potential pathway for the spread of this fungus. This fungus spreads locally through rain-splash of sporangia formed on the foliage of certain hosts; for example, *Umbellularia californica*, *Larix kaempferi*, *Rhododendron ponticum*, 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, 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; Davidson et al. 2005; Werres et al. 2001). 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.

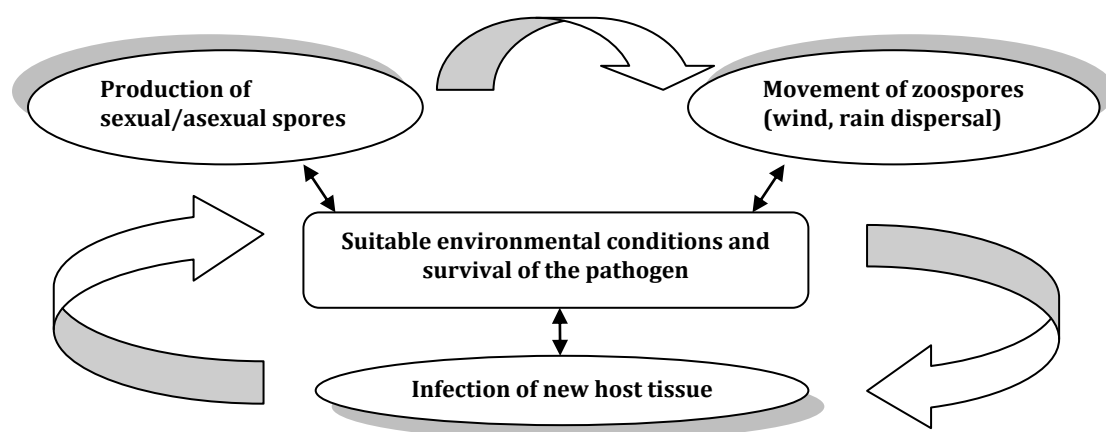
The first step in the life cycle of aerially dispersed *Phytophthora* species is the production of infective spores on or within living plant tissue (foliage, green stems and woody stems). Foliar hosts (bay laurel, Japanese larch and *Rhododendron* species) are an important source of inoculum for initiating 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 degrees Celsius.

Phytophthora ramorum requires a susceptible foliar host that supports high levels of sporulation (for example, *Rhododendron ponticum*, *Vaccinium* species, *Quercus ilex*, *Rhamnus alaternus*, *Viburnum tinus* and *Arbutus unedo*). 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 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 is 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 also disperse over long distances in rivers and streams with propagules having been detected up to 1–20 kilometers 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 (10–15 meters) of *P. ramorum* has been reported in evergreen forests in California (Davidson et al. 2005). In Oregon, rain-splash and long distance *Phytophthora ramorum* dispersal (0–4 kilometers) in turbulent air currents has been reported (Mascheretti et al. 2008; Hansen 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). Possibilities of spread through other human-mediated means include 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 among 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* 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 8–11 months in the soil (Shishkoff 2007) and subsequent 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 (8–11 months) and growing media (> 12 months) (Shishkoff 2007; Linderman & Davis 2006a). 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 Sudden oak death (SOD) and *P. ramorum* in California and Oregon (Hansen et al. 2003a). A similar survey in the UK found *P. kernoviae*, which was isolated most frequently from *Fagus sylvatica*, but also from necrotic lesions of *Quercus robur* and *Liriodendron tulipifera* (Brasier et al. 2005). These newly identified *Phytophthora* species share commonality with *P. ramorum* in several biological aspects, including the production of deciduous sporangia adapted for aerial dispersal, similar host ranges, and occur in generally the same geographic region (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*) fulfil the International Plant Protection Convention (IPPC) criteria for a quarantine pest and are not present in Australia. In this PRA, nursery stock, including ornamental plants and propagative material (dormant hardwood 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, 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 nursery stock (including ornamental plants and 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 pathway.

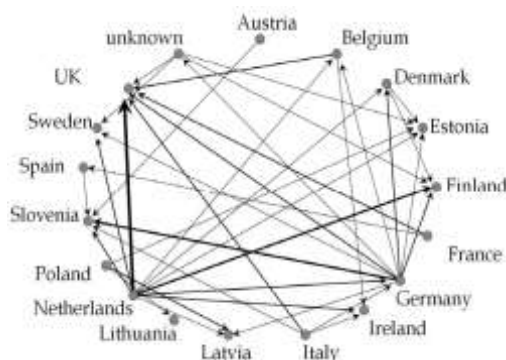
- The historical introduction of *P. ramorum* into California is linked to the nursery trade (Ivors et al. 2006; Mascheretti et al. 2008). *Phytophthora ramorum* was introduced into the USA and Europe via imported *Camellia*, *Rhododendron* or *Viburnum* nursery stock (Brasier 2007); therefore, the nursery 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 will 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, at times, 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 into various countries on *Camellia japonica*, *Kalmia latifolia*, *Leucothoe* species, *Pieris formosa* var. *forrestii*, *Pieris 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*) to 21 states in the USA (Cave et al. 2008); with infected *Rhododendron* 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 is 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 ranges from 10–18 degrees Celsius and 85–90 percent relative humidity (McGregor 1987). *Phytophthora ramorum* has an optimum temperature range for survival and reproduction of 18–25 degrees Celsius, with a minimum growth temperature of 2 degrees Celsius and a maximum growth temperature of 26–30 degrees Celsius (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 (Parke & Lewis 2007; Pogoda & Werres 2004), 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 degrees Celsius and 25 degrees Celsius (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 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; Rytönen 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; Swain et al. 2002; 2006; Aveskamp & Wingelaar 2005). 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* (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 fertilization (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* 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 the 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 37.5–40 degrees Celsius are lethal to *P. ramorum* hyphae within several hours, and that 42.5–50 degrees Celsius 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 degrees Celsius 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 3).

- The likelihood that the *Phytophthora* species will enter Australia with imported nursery stock (including ornamental plants and 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 nursery stock (including ornamental plants and 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* and *Kalmia latifolia* (DEFRA 2004). Foliar hosts including *Rhododendron* 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.

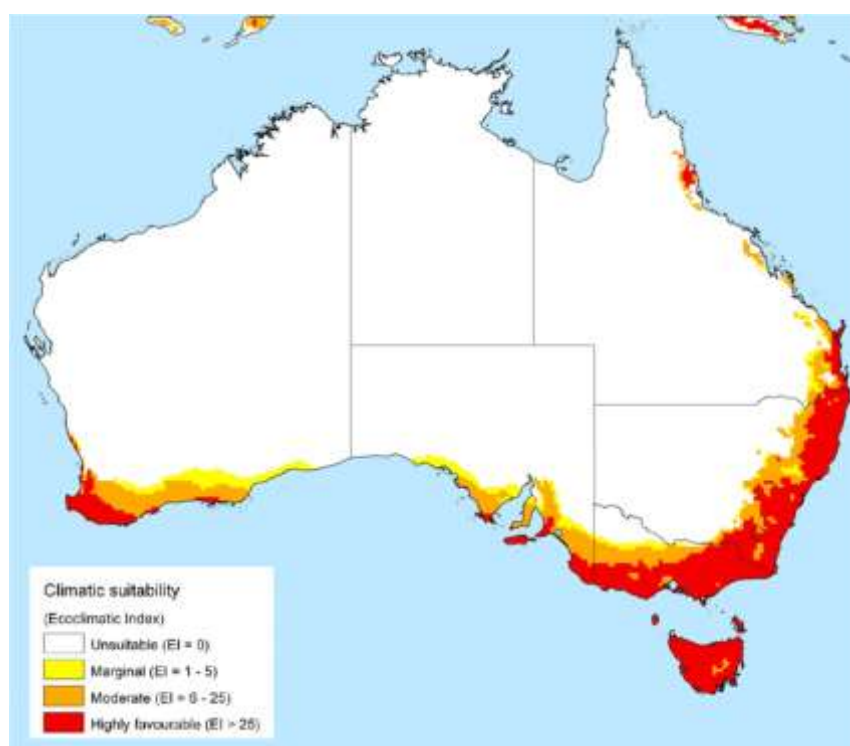
- Several host genera of *P. ramorum* are widely distributed in temperate and Mediterranean regions and grow in gardens, parks, streetscapes and native plant communities in parts of Australia (Appendix A). They include genera that are cultivated (*Arbutus* species, *Quercus* species, *Rhododendron* species, *Viburnum* species), naturalised (*Acer* species, *Lonicera* species, *Salix* species) and native (*Adiantum* species, *Cinnamomum* species, *Dryopteris* species, *Eucalyptus* species, *Euonymus* species, *Gaultheria* species, *Ilex* species, *Nothofagus* species, *Pittosporum* species, *Rhododendron* species, *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*), 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; EPP0 2012; FERA 2012; Sansford et al. 2009; Gomes & Amaro 2009; 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 degrees Celsius with a minimum growth temperature of 2 degrees Celsius and a maximum growth temperature of 26–30 degrees Celsius (Werres et al. 2001). Infection does not occur below 10 degrees Celsius and above 30 degrees Celsius. 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 degrees Celsius 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 degrees Celsius and 25 degrees Celsius (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 (Davidson et al. 2003b; Parke et al. 2002a; Werres et al. 2001).
 - 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, 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* 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 climate 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). Studies demonstrate that temperatures of 37.5–40 degrees Celsius are lethal to *P. ramorum* hyphae within several hours and temperatures of 42.5–50 degrees Celsius are lethal

within a matter of minutes (Browning et al. 2008); however, such extreme temperatures will not occur in nature.

- The survival of *P. ramorum* at extreme temperatures is likely to occur in colonised plant tissues—attached leaves and stems, and decomposing leaves in contact with soil. When *P. ramorum* was present in infected *Rhododendron* leaves, in the form of chlamydospores and perhaps hyphae, survival at 35 degrees Celsius declined within two days, with no survival observed by the fourth day (Tooley et al. 2008).
- 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 nursery stock (including ornamental plants and 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* hosts are widespread in Australia. Foliar hosts, including many Ericaceae, 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. Due to high susceptibility and the 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, produce 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* includes 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 up to 10–20 meters depending on the 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 3 kilometers may occur in storm winds (Rizzo et al. 2005).

- Short distance spread of *Phytophthora* occurs on a yearly basis and is normally within a few kilometres, but 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, only occurring in the presence of winds strong enough to pick up sporangia (Mascheretti et al. 2008). Sporangia can be spread from 1–5 kilometers from the source (Mascheretti et al. 2008).
- Infected nursery stock is unlikely to be grown in isolation; therefore 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* (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* is 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* 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

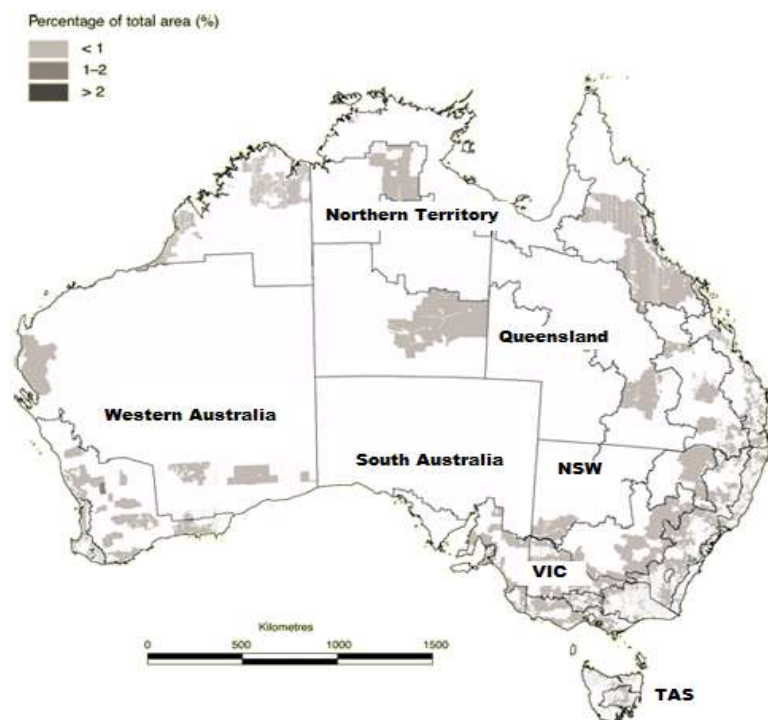
- *Phytophthora ramorum* has the potential for natural and human mediated spread. Natural spread of *P. ramorum* is through air-borne inoculum (Davidson et al. 2005). Sporangia are primarily dispersed short distances by rain-splash; therefore, its rate of non-facilitated spread may generally be limited (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*, *Ilex*, *Griselinia*, *Hamamelis*, *Kalmia*, *Laurus*, *Leucothoe*, *Lonicera*, *Magnolia*, *Michelia*, *Osmanthus*, *Parrotia*, *Photinia*, *Pieris*, *Rhododendron*, *Ribes*, *Syringa*, *Taxus*, *Umbellularia*, *Vaccinium* and *Viburnum* (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 degrees Celsius, 18 degrees Celsius, and 26 degrees Celsius, respectively (Brasier et al. 2005). Similarly, *Phytophthora ramorum* has an optimum temperature range of 18–25 degrees Celsius 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 degrees Celsius, 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 *Phytophthora ramorum* is mostly at a relatively small scale (1–10 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 degrees Celsius (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 1 kilometer) semi-natural environments (Jeger et al. 2007). The large sporangia can be picked up by strong winds and deposited 1–3 kilometers 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, 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 imported infected host material is 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 among (and within) 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*, *Pieris japonica*, *Rhododendron*, *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 8–11 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 8 kilometers 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* species, *Camellia* species, *Hamamelis* species, *Kalmia* species, *Pieris* species, *Rhododendron* species and *Syringa* species; therefore, *P. ramorum* could spread with trade in cut flower 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 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, of establishment and of spread using the matrix of 'rules' for combining qualitative likelihoods shown in Table 3.

- The likelihood that the *Phytophthora* species will enter Australia on nursery stock (including ornamental plants and 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 4. 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	<p>E – Significant at the regional level</p> <p><i>Phytophthora ramorum</i> 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). <i>Phytophthora ramorum</i> has the potential to cause economic consequences as it attacks hosts with significant commercial value, directly causes tree mortality and may cause market loss due to its presence and significant quarantine status.</p> <ul style="list-style-type: none"> • <i>Phytophthora ramorum</i> is capable of killing healthy mature oak, tan oak, Japanese larch, wild <i>Rhododendron</i> species, evergreen huckleberries and <i>Viburnum</i> species. Thousands of <i>Lithocarpus</i> and <i>Quercus</i> plants have been killed in California and Oregon (Rizzo et al. 2005). Direct mortality has also been recorded in <i>Arbutus</i>, <i>Fagus</i>, <i>Rhododendron</i> and <i>Vaccinium</i>. This pathogen also causes tip dieback on several hosts, and disfiguring leaf spots on several common nursery species, thereby rendering the plants unmarketable. • Susceptible hosts include plants of importance to the nursery industry with amenity value in parks and gardens (<i>Acer</i>, <i>Quercus</i>, <i>Pieris</i>, <i>Prunus</i>, <i>Rosa</i>) some of which are of both key epidemiological importance and highly prized ornamentals (<i>Camellia</i>, <i>Rhododendron</i>, <i>Viburnum</i>). • Adverse effects on the health of trees of historic importance in town streetscapes, cemeteries, churchyards (<i>Taxus</i>) and orchard crops (<i>Castanea</i>) may occur. <i>Castanea sativa</i> is valuable in the commercial production of sweet chestnuts and gourmet mushrooms. Hosts include plants occurring in plantation and native forests which are the primary species on which the Australian timber industry is based (<i>Eucalyptus</i>, <i>Pinus</i>). • The economic impact on plant life or health may depend on the extent of symptom 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, but resulting mainly in yield reductions and enhanced susceptibility to other stresses.
Other aspects of the environment	<p>E – Significant at regional level</p> <p>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.</p> <ul style="list-style-type: none"> • 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. • There is a relationship between <i>P. ramorum</i> and fire in forests in the Mediterranean regions of the USA. Foliar moisture contents of infected tanoak is lower (Kuljian & Varner 2010) and the decrease in 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 <i>P. ramorum</i> outbreak in the Mediterranean, where forests and shrublands are already particularly vulnerable to fires. • The implications of <i>P. ramorum</i> on natural ecosystems, agriculture and horticulture

Criterion	Estimate and rationale
	may potentially be far worse than that currently posed by <i>P. cinnamomi</i> (O’Gara et al. 2005).
Indirect	
Eradication, control, etc.	<p>E – Significant at the regional level</p> <p>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) at the 10 meter to 5 kilometer scale makes this a difficult pathogen to eradicate once introduced into the wild (Prospero et al. 2007).</p> <ul style="list-style-type: none"> 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 movements of soil (Rizzo et al. 2005). Appropriate disposal of <i>P. ramorum</i> infected green waste is considered a major economic issue for quarantined counties in California (Cave et al. 2005). The need for management and precautionary and sanitary practises and 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 government (CABI 2014). In addition, implementation of extensive disease surveillance and sampling programs may be required to ensure the early detection and to contain further spreading of the pathogen once it has established in the landscape, as in the USA (Goheen et al. 2006a).
Domestic trade	<p>E – Significant at the regional level</p> <ul style="list-style-type: none"> The presence of <i>P. ramorum</i> 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 <i>P. ramorum</i> became established in Australia. Restrictions might apply to domestic trade in nursery stock, forest products and other commodities.
International trade	<p>E – Significant at the regional level</p> <ul style="list-style-type: none"> Because of the threat <i>P. ramorum</i> 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 <i>P. ramorum</i> 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 <i>P. ramorum</i> 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	<p>E – Significant at the regional level</p> <ul style="list-style-type: none"> 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, and may impact on other activities. Native Americans are concerned that the effect of <i>P. ramorum</i> 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 5, that is, where the potential consequences of a pest with respect to all criteria have an impact of 'E', the overall consequences are estimated to be **HIGH**.

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 6.

Unrestricted risk estimate for *Phytophthora ramorum*

Overall likelihood of entry, establishment and spread	HIGH
Consequences	HIGH
Unrestricted risk	HIGH

As indicated, the unrestricted risk estimate for the *Phytophthora* species has been assessed as 'high', 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.

5.1 Existing risk mitigation measures

Currently, there are two separate sets of conditions that apply to *Phytophthora ramorum* host propagative material: conditions for sourcing propagative material from (1) *Phytophthora ramorum* countries and (2) non-*Phytophthora ramorum* countries. Australia's existing risk management for *Phytophthora* host propagative material from all sources is based on tiered safeguards. That is, if one mitigating measure fails, other safeguards exist to ensure that the risk is progressively reduced and managed.

Table 8 Summary of existing risk mitigation measures for *Phytophthora ramorum* host propagative material

Existing conditions	Bare-rooted plants	Dormant cuttings (a)	Tissue cultures
<i>Phytophthora ramorum</i> countries			
Import permit is required	-	Yes	Yes
Mandatory on-arrival inspection	-	Yes	Yes
Mandatory methyl-bromide fumigation (b)	-	Yes	No
Mandatory surface sterilization (c)	-	Yes	No
Mandatory growth in PEQ (d)	-	Yes	Yes
Non-<i>Phytophthora ramorum</i> countries			
Import permit is required	Yes	Yes	Yes
Additional declaration (e)	Yes	Yes	Yes
Mandatory on-arrival inspection	Yes	Yes	Yes
Mandatory methyl-bromide fumigation	Yes	Yes	No
Mandatory growth in PEQ (f)	Yes	Yes	Yes

(a) Unrooted dormant hardwood budwood or cuttings of a limited number of genera are permitted. **(b)** Imported dormant cuttings are subject to mandatory methyl-bromide fumigation (T9060). **(c)** Imported dormant cuttings are surface sterilised with Sodium hypochlorite (T9374). **(d)** Dormant cuttings from all sources are grown in closed PEQ facilities and are subject to pathogen screening. Tissue cultures (microplantlets) from all sources are grown in closed PEQ facilities and subject to pathogen screening. **(e)** Propagative material accompanies an official government Phytosanitary Certificate with an additional declaration that 'Sudden Oak Death (*Phytophthora ramorum*) is not known to occur in [insert country of origin]'. **(f)** Propagative material from non-*Phytophthora ramorum* countries is grown in closed PEQ facilities and is subject to pathogen screening.

5.2 Review of existing risk mitigation measures

As part of the review, the department has updated the natural host list of *Phytophthora kernoviae*, *Phytophthora nemorosa*, *Phytophthora pseudosyringae* and *Phytophthora ramorum*.

5.2.1 Regulatory approach—the pathogen

The existing policy to regulate *P. ramorum* associated with forest and ornamental plants is proposed to continue.

- The International Plant Protection Convention (IPPC) of the Food and Agriculture Organization of the United Nations (FAO) and the World Trade Organisation (WTO) have recognised the phytosanitary concerns related to the expanding world trade. Consequently, international protocols to control the process of trade were setup. The aim of the protocols was to reduce the likelihood of the accidental introduction of pests into new areas.
- The department acknowledges that under the current international phytosanitary framework, led by the Secretariat of the IPPC and required by the WTO SPS Agreement, there is no process by which phytosanitary measures can be imposed against an unidentifiable cause. Consequently, international plant health protocols are list-based, allowing regulation of only named organisms; however, it is possible to regulate at the genus level provided the organism is identified as being unique (FAO 2013a). On-going research in response to *P. ramorum* has resulted in, and may result in, the identification of new *Phytophthora* species in the ecosystem. Therefore, if an unknown *Phytophthora* is identified that is economically important, emergency measures may be imposed.

5.2.2 Regulatory approach—the host

The existing policy to regulate all species that belong to a genus that includes a natural host of *P. ramorum* is proposed to continue.

- All susceptible species are not yet known; therefore, the department considers that all species within a regulated genus are considered to pose a similar potential quarantine risk to Australia, until otherwise demonstrated as meeting Australia's ALOP.
- The department considers that the list of genera for regulation may not include all known natural hosts as these are continually being identified. The host list may therefore be amended from time to time to reflect these additions; and amendments will be notified on the department's import conditions database (<http://www.agriculture.gov.au/biosecurity/import/icon-icd>).
- The department acknowledges that *P. kernoviae*, *P. nemorosa*, and *P. pseudosyringae* have multiple overlapping hosts (Webber 2008; Yakabe et al. 2009; Grünwald et al. 2011) and symptoms produced on shared hosts are indistinguishable to *P. ramorum*. However, there may be a few hosts specific to one of the *Phytophthora* species other than *P. ramorum* under review. For example, *Annona cherimola* (custard apple) is

only known as a host of *P. kernoviae*. It is therefore proposed that natural host lists are updated accordingly.

- The department considers that the isolation of *P. ramorum* from tree species in the field that were previously identified as potential hosts in artificial inoculations (Brasier et al. 2004b), but later found to be natural hosts, highlights the importance of identifying potential hosts from disease-free countries. *Rhododendron* is a known host of multiple *Phytophthora* species including *P. ramorum* and *P. kernoviae*. Symptomless foliar infections were observed on *Rhododendron macrophyllum* and *Rhododendron occidentale* when exposed to *P. kernoviae* (Fichtner et al. 2011). Knowledge of potential hosts and therefore, carriers of the pathogen, will provide data to develop robust quarantine systems to prevent the inadvertent introduction of *Phytophthora* species into Australia.

5.2.3 Propagative material from non-*Phytophthora ramorum* countries

Existing conditions (including Phytosanitary Certification with an additional declaration of country freedom, on arrival inspection, treatment and growth in the PEQ) for *Phytophthora ramorum* host propagative material (tissue cultures, dormant hardwood cuttings, budwood and bare-rooted plants) from non-*Phytophthora ramorum* countries is proposed to continue. It is proposed that the other *Phytophthora* species, *Phytophthora kernoviae*, *Phytophthora nemorosa* and *Phytophthora pseudosyringae*, should also be included in the additional declaration.

5.2.4 Propagative material from *Phytophthora ramorum* countries

The importation of all rooted plants of hosts of *Phytophthora ramorum* is prohibited from all countries where this pathogen is known to occur.

5.2.5 Regulatory approach—form of propagative material

Between 2002 and 2013, Australia restricted all imports of *P. ramorum* hosts to tissue cultures (microplantlets) only from countries where this pathogen is established.

Tissue cultures (microplantlets)

- Industry generally supported this policy and accepted the measures above as *P. ramorum* was newly described, epidemiology was unknown and no reliable detection method was available; and economic consequences of the pathogen were high.
- Micropropagation of plants from an apical meristem has been used as a reliable method of eliminating pathogens and represents an inherently lower risk than other forms of nursery stock (budwood, cuttings and live plants). The non-detection of *P. ramorum* in tissue cultures imported into Australia demonstrated that this import pathway is low risk and is therefore supported to continue.
- However, restricting the imports of host material to tissue cultures effectively prohibited imports of host material that cannot be easily propagated through tissue culture from countries where *P. ramorum* is present.

Dormant hardwood cutting material and budwood

In 2013, dormant hardwood cutting material or budwood of host propagative material of 13 genera that are difficult to tissue culture were allowed from countries where *P. ramorum* is known to occur.

- Currently there is no age limit on cuttings and budwood of *P. ramorum* host material. It is proposed that imported cuttings and budwood be restricted to one-year-old dormant cuttings.
 - Restricting cuttings to one-year-old material increases the likelihood of pathogen detection as symptoms are more obvious on young tissue.
- Restricting imports to tissue cultures, dormant hardwood cutting material and budwood may still be trade restrictive. Consequently, the department proposes to allow imports of one-year-old bare-rooted plants without foliage with additional risk mitigation measures.

5.2.6 Mandatory on arrival inspection (dormant cuttings, budwood, tissue cultures)

The existing requirement for mandatory on-arrival inspection of imported propagative material (cuttings, budwood) to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern is proposed to continue.

Freedom from disease symptoms will be adequate for the detection of visible symptoms caused by *Phytophthora* species; therefore, existing mandatory on arrival inspection to verify freedom from disease symptoms is proposed to continue.

The leaf, shoot or stem symptoms are not unique to *P. ramorum*, and therefore, the pathogen can be difficult to identify. Infected plants may be easily missed since similar symptoms can be caused by other plant pathogens. For example, in *Rhododendron*, infected leaves are easily overlooked and are therefore not always easy to observe. *Phytophthora ramorum* chlamydospores are found in asymptomatic roots of *Rhododendron* (Sundheim *et al.* 2009) and sporulation from naturally infected but asymptomatic foliage is reported (Denman *et al.* 2008). Symptoms of *P. ramorum* may also be masked by the use of fungicides that suppress disease development without eradicating the pathogen (Tjosvold *et al.* 2005).

There are concerns that latent infections might go undetected (Cave *et al.* 2008). The duration of latent infections depends on the host species involved and may not be detected at the time of inspection. The symptomless nature of these pathogens indicate that visually healthy plants may harbour a sporulating pathogen in the roots or the foliage, in other words, visual inspection alone may be insufficient. *Phytophthora ramorum* and *P. kernoviae* are known to cause latent infections on certain hosts and are capable of producing spores without producing any symptoms (Denman *et al.* 2008; Vettraino *et al.* 2009). Reliance solely on on-arrival visual inspection therefore does not adequately mitigate the risk of *Phytophthora* species entering Australia on cuttings and

budwood. Therefore, additional risk management measures are required for these pathogens.

Freedom from soil and extraneous material will be adequate to mitigate the risk of soil-borne pathogens. The *Phytophthora* species under review are known to survive in the soil; for example, *Phytophthora ramorum* can survive for at least 8–11 months in soil (Shishkoff 2007). Soil contaminated with sporangia, oospores or chlamydospores provide a pathway for the introduction and spread of the pathogen into Australia (Hansen et al. 2000). Therefore, it is proposed that the requirement for imported propagative material to be free from soil and other extraneous contamination of quarantine concern be maintained, in-line with general nursery stock import conditions, to prevent the potential introduction of soil-borne pests. Although not directly related to the commodity itself, there are many plant pests that can be found in the soil which are able to remain viable in that environment for several years. These pests can be spread by the movement of contaminated soil.

5.2.7 Mandatory on arrival treatment for cuttings and budwood

The existing requirement for mandatory on-arrival fumigation (T9060) of imported cuttings and budwood is proposed to continue. However, insecticidal dip is proposed as an alternative to mandatory methyl bromide fumigation.

5.2.8 Mandatory growth in closed PEQ

The existing requirement for growth in a PEQ facility is an appropriate phytosanitary measure for the safe introduction of *Phytophthora* host propagative material (tissue cultures, dormant cuttings and budwood). Therefore, the existing requirement for mandatory growth under closed quarantine, at a government PEQ facility for pathogen screening is supported; however, the department considers that the growth period in the PEQ facilities requires further improvements.

Tissue cultures (microplantlets)

- Tissue cultures currently require mandatory growth in PEQ for a minimum of 12 months for passive pathogen screening (PEQ periods may vary for tissue culture SOD hosts due to other high risk pathogens). Therefore, the existing requirement for mandatory growth of tissue cultures under closed quarantine, at a government PEQ facility for pathogen screening is supported and it is proposed that visual inspection should be supplemented with molecular tests including a generic *Phytophthora* PCR test.
 - Micropropagation (tissue cultures) is a powerful tool for the propagation and sanitary improvement of many woody plant species. Movement of planting material *in vitro* cultures is the safest method, as *in vitro* techniques (tissue cultures) are effective in eliminating many pathogens.

Cuttings and budwood

- Cuttings and budwood are currently required to be grown in PEQ for 24 months. The department considers that this requirement should be revised and that the growth

time in PEQ could be reduced by the introduction of several safeguards including cultural and molecular techniques.

- In naturally-infected *Quercus* and *Lithocarpus* Californian forests, the apparent latent period may range from less than one year to two or more years (Swiecki & Berhardt 2010). In contrast, other reports suggest that there is little evidence for latency of infection; for example, under controlled environments, lesions were present within five days in *Rhododendron* leaves (DEFRA 2004).
- *Phytophthora ramorum* symptoms are expressed within three months of active growth of the pathogen (de Hoop 2002); however, if fungicides are used it may take three to six months for chemical activity to subside and for the growth of *Phytophthora* to resume within infected plants (Goheen et al. 2006b).
- Under controlled environments, asymptomatic infection and sporulation endured for at least eight to ten days (Denman et al. 2008).
- Based on these observations it is proposed that the PEQ growth period could be reduced to 15 months.

5.3 Proposed risk mitigation measures for propagative material from *Phytophthora ramorum*, *P. kernoviae*, *P. nemerosa* and *P. pseudosyringae* countries

The current review proposes pro-active testing and a reduction in the growth period in PEQ. The current review also proposes to allow bare-rooted plants from countries where these *Phytophthora* species are known to occur. Proposed testing procedures are based on active testing for all four *Phytophthora* species using modern molecular techniques. This approach allows imported propagative material to be screened for a minimum period of 15 months in PEQ instead of the current 24 months.

5.3.1 Regulatory approach—the host

This review proposes that the regulations be lifted for experimental hosts of *Phytophthora ramorum*.

5.3.2 Tissue cultures (microplantlets)

The existing policy requirements of mandatory on-arrival inspection and growth in a PEQ facility are supported in this review. It is proposed that imported tissue cultures be well rooted prior to arrival as this helps in their establishment out of agar into the growth media.

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.

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. Tissue cultures must be

grown in closed government PEQ facilities for a period of observation, and until the required pathogen screening/testing is completed.

- Appropriate environmental conditions (temperature and humidity) are important for symptom expression; therefore, it is proposed that tissue cultures be grown in mist beds/fog for the first six weeks at 19–25 degrees Celsius to favour symptom expression for all four *Phytophthora* pathogens.
- *Phytophthora ramorum* and *P. kernoviae* are known to cause latent infections on certain hosts and are capable of producing spores without producing any symptoms (Denman et al. 2008; Vettraino et al. 2009). Under controlled environments, latent infection and sporulation endure for at least eight days, and can be as long as 22 days (Denman et al. 2008). However, in naturally-infected *Quercus* and *Lithocarpus* in Californian forests (mature trees) the apparent latent period may range from less than one year to two or more years (Swiecki & Bernhardt 2006).
- Under a controlled environment, the time period between infection and appearance of symptoms of *P. ramorum* decreases with increasing temperatures (DEFRA 2004). The symptoms appeared within five days at 25 degrees Celsius after inoculation (DEFRA 2004); therefore, growing tissue cultures for the first six weeks at 19–25 degrees Celsius will assist with disease expression and pathogen detection.
- It is proposed that during the PEQ growth period, tissue culture plantlets are subjected to visual inspection and molecular testing. Although visual assessment is an important method for screening pathogens, tissue cultures may be infected and not produce any obvious disease symptoms due to cultivar susceptibility, environmental conditions or other plant related factors.
- The proposed pathogen testing during growth in PEQ will include active testing for *Phytophthora* species using molecular tests including, but not limited to, PCR. It is proposed that generic *Phytophthora* PCR of leaf tissues for each plant be carried out to verify freedom from *Phytophthora* species.

5.3.3 Dormant cuttings and budwood

This review proposes that the existing conditions (mandatory on-arrival inspection, fumigation, culturing, sodium hypochlorite treatment and growth in the PEQ facility) for 13 genera currently allowed entry into Australia be extended to all natural hosts of *Phytophthora* species under review.

It is proposed that imported cuttings and budwood should be of one-year-old only. Cuttings should also 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 imported dormant cuttings must be subjected to the following conditions.

Mandatory on-arrival inspection

Imported dormant cuttings must be subjected to mandatory on-arrival inspection to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern.

- The *Phytophthora* species under review are known to survive in the soil; for example, *Phytophthora ramorum* can survive for at least 8–11 months in soil (Shishkoff 2007). Soil contaminated with sporangia, oospores or chlamydospores provide a pathway for the introduction and spread of the pathogen (Hansen et al. 2000); therefore, dormant cuttings or budwood should be free from soil.
- Mandatory on-arrival inspection will be effective to detect pathogens producing obvious disease symptoms; however, *P. ramorum* and *P. kernoviae* are known to cause latent infections on certain hosts and are capable of producing spores without producing any symptoms (Denman et al. 2008; Vettraino et al. 2009). The symptomless nature of these pathogens indicates that visually healthy plants may harbour a sporulating pathogen; therefore, visual inspection alone may be insufficient.

Reliance solely on on-arrival visual inspection therefore does not adequately mitigate the risk of *Phytophthora* species entering Australia on dormant cuttings. Therefore, additional risk management measures are required for dormant cuttings.

Mandatory on-arrival treatment

Imported dormant cuttings must be subjected to mandatory on-arrival methyl bromide fumigation or insecticidal dip.

Mandatory culturing on-arrival

It is recommended that following the mandatory methyl bromide fumigation or insecticidal dip, macerated buds from dormant cuttings be cultured to detect fungal pathogens. This broad spectrum culturing test is useful to screen imported dormant cuttings for fungal pathogens.

Mandatory molecular testing

It is proposed that stem tissues from imported cuttings and budwood must be removed and subjected to mandatory generic *Phytophthora* PCR. The *Phytophthora* species under review have a significant aerial component of their life cycle (Davidson et al. 2005; 2008; Martin et al. 2012). Therefore, pre-screening for *Phytophthora* species will minimise the risk of introducing these pathogens into the PEQ production system.

Mandatory sodium hypochlorite treatment

Imported dormant cuttings must be subjected to sodium hypochlorite treatment (1% NaOCl for five minutes) for surface sterilisation (T9474).

Mandatory growth in PEQ facilities

It is proposed that imported cuttings be grown in a closed government PEQ facility for a minimum period of 15 months instead of 24 months. The purpose of growth in PEQ

facilities is to screen imported propagative material for *Phytophthora* species in order to prevent the introduction of these pathogens into Australia.

- Appropriate environmental conditions (temperature and humidity) are important for symptom expression; therefore, it is proposed that dormant cuttings be grown in mist beds/fog for the first six weeks at 19–25 degrees Celsius to favour symptom expression for all four *Phytophthora* pathogens.
- *Phytophthora ramorum* and *P. kernoviae* are known to cause latent infections on certain hosts and are capable of producing spores without producing any symptoms (Denman et al. 2008; Vettraino et al. 2009). Under controlled environments, latent infection and sporulation endure for at least eight days, and can be as long as 22 days (Denman et al. 2008). However, in naturally-infected *Quercus* and *Lithocarpus* in Californian forests (mature trees) the apparent latent period may range from less than one year to two or more years (Swiecki & Bernhardt 2006).
- Under a controlled environment, the time period between infection and appearance of symptoms of *P. ramorum* decreases with increasing temperatures (DEFRA 2004). The symptoms appeared within five days at 25 degrees Celsius (DEFRA 2004); therefore, growing dormant cuttings for the first six weeks at 19–25 degrees Celsius will assist with disease expression and pathogen detection.
- It is proposed that during the PEQ growth period, plants are subjected to visual inspection and molecular testing. Although visual assessment is an important method for screening pathogens, dormant cuttings may be infected and not produce any obvious disease symptoms due to cultivar susceptibility, environmental conditions or other plant related factors.
- The proposed pathogen testing during growth in PEQ will include active testing for *Phytophthora* species using molecular tests including, but not limited to, PCR. It is proposed that 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.

5.3.4 Bare-rooted plants

It is proposed that only one-year-old bare-rooted plants be permitted. Bare-rooted plants (a maximum of ten/cultivar) 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.

Phytosanitary Certificate

It is proposed that bare-rooted plants must be accompanied by an official government Phytosanitary Certificate with an additional declaration that the rooted cuttings have been inspected by the NPPO and found free of obvious disease symptoms (*Phytophthora* species).

Mandatory on-arrival inspection

It is proposed that imported bare-rooted plants without foliage must be subjected to mandatory on-arrival inspection to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern.

- The *Phytophthora* species under review are known to survive in the soil; for example, *P. ramorum* can survive for at least 8–11 months in soil (Shishkoff 2007). Soil contaminated with sporangia, oospores or chlamydospores can provide a pathway for the introduction and spread of the pathogen (Hansen et al. 2000); therefore, bare-rooted plants should be free from soil.
- Mandatory on-arrival inspection will be effective to detect pathogens producing obvious disease symptoms; however, *P. ramorum* and *P. kernoviae* are known to cause latent infection on certain hosts and are capable of producing spores without producing any symptoms (Denman et al. 2008; Vettraino et al. 2009).
- The *Phytophthora* species under review are known to survive in infected foliage and roots (Fichtner et al. 2011). It is reported that asymptomatic roots of infected *Rhododendron* species harbour chlamydospores of *P. ramorum* (Riedel et al. 2009). These studies indicate that visually healthy plants may harbour a sporulating pathogen in the roots, in other words, visual inspection alone may be inadequate.

Reliance solely on on-arrival visual inspection therefore does not adequately mitigate the risk of *Phytophthora* species entering Australia on bare-rooted plants. Additional risk management measures are required for these pathogens.

Mandatory on-arrival treatment

Imported bare-rooted plants must be subjected to mandatory on-arrival methyl bromide fumigation or insecticidal dip.

Mandatory culturing on-arrival

It is recommended that following the mandatory methyl bromide fumigation or insecticidal dip, macerated buds from bare-rooted plants be cultured to detect fungal pathogens. This broad spectrum culturing test is useful to screen imported bare-rooted plants for fungal pathogens.

Mandatory molecular testing on-arrival

It is proposed that plant tissues from imported bare-rooted plants must be removed and subjected to a mandatory generic *Phytophthora* PCR testing on arrival to verify freedom from pathogens. If *Phytophthora* species are detected then specific PCR tests should be carried out.

The *Phytophthora* species under review are known to survive in infected roots without producing any symptoms (Fichtner et al. 2007a, b; 2011). Therefore, pre-screening for *Phytophthora* species will minimise the risk of introducing these pathogens into the PEQ production system.

Mandatory sodium hypochlorite treatment

It is proposed that bare-rooted plants be subjected to a sodium hypochlorite treatment (1% NaOCl for five minutes) for surface sterilisation. Treatment with sodium hypochlorite should be undertaken after the results of the PCR.

Mandatory growth in PEQ facilities

It is proposed that imported bare-rooted plants be grown in a closed government PEQ facility for a minimum period of 15 months. The purpose of growth in PEQ facilities is to screen imported propagative material for *Phytophthora* species in order to prevent the introduction of these pathogens into Australia.

- Appropriate environmental conditions (temperature and humidity) are important for symptom expression; therefore, it is proposed that bare-rooted plants are grown in mist beds/fog for the first six weeks at 19–25 degrees Celsius to favour symptom expression for all four *Phytophthora* pathogens.
- *Phytophthora ramorum* and *P. kernoviae* are known to cause latent infections on certain hosts and are capable of producing spores without producing any symptoms (Denman et al. 2008; Vettraino et al. 2009). Under controlled environments, latent infection and sporulation endure for at least eight days, and can be as long as 22 days (Denman et al. 2008). However, in naturally-infected *Quercus* and *Lithocarpus* in Californian forests (mature trees) the apparent latent period may range from less than one year to two or more years (Swiecki & Bernhardt 2006).
- Under a controlled environment the time period between infection and appearance of symptoms of *P. ramorum* decreases with increasing temperatures (DEFRA 2004). The symptoms appeared within five days at 25 degrees Celsius after inoculation (DEFRA 2004); therefore, growing bare-rooted plants for the first six weeks at 19–25 degrees Celsius will assist with disease expression and pathogen detection.
- It is proposed that during the PEQ growth period, plants are subjected to visual inspection, culturing and molecular testing. Although visual assessment is an important method for screening pathogens, bare-rooted plants may be infected and not produce any obvious disease symptoms due to cultivar susceptibility, environmental conditions or other plant related factors.
- The proposed pathogen testing during growth in PEQ will include active testing for *Phytophthora* species using molecular tests including, but not limited to, PCR. It is proposed that generic *Phytophthora* PCR testing of leaf tissues for each plant be carried out. If *Phytophthora* species are detected then additional identification or molecular testing should be carried out.

A summary of the proposed risk management measures for bare-rooted plants, dormant cuttings and tissue cultures from *Phytophthora ramorum*, *P. kernoviae*, *P. nemerosa* and *P. pseudosyringae* countries is provided in Table 9.

Table 9 Proposed risk mitigation measures for propagative material from *Phytophthora ramorum*, *P. kernoviae*, *P. nemerosa* and *P. pseudosyringae* countries

Proposed measures	Commodity		
	Bare-rooted plants	Dormant cuttings	Tissue cultures
On-arrival measures			
Phytosanitary certificate	Yes (Additional declaration that inspected by NPPO and found free of obvious disease symptoms)	Not specified	Not specified
On-arrival inspection	Yes	Yes	Yes
Methyl bromide fumigation or insecticidal dip	Yes	Yes	No
Culturing	Yes	Yes	No
On-arrival molecular testing	Yes (Generic PCR)	Yes (Generic PCR)	No
Sodium hypochlorite treatment	Yes	Yes	No
Mandatory growth in PEQ	Yes (minimum 15 months)	Yes (minimum 15 months)	Yes (minimum 12 months)
Visual inspection during PEQ	Yes	Yes	Yes
Molecular testing during PEQ	Yes (Generic PCR)	Yes (Generic PCR)	Yes (Generic PCR)

5.4 Consideration of alternative measures

Consistent with the principle of equivalence detailed in ISPM 11: *Pest risk analysis for quarantine pests* (FAO 2013b), the department will consider any alternative measure proposed by the exporting NPPO, providing that it achieves Australia's ALOP. Evaluation of such measures or treatments will require a technical submission from the exporting NPPO that details the proposed treatments or measures, including data from suitable treatment trials to demonstrate efficacy.

A number of risk mitigation measures designed to protect and minimise the risks of exotic pests under International Plant Protection Convention (IPPC) standards (www.ippc.int/IPP/En/default.jsp) are considered below.

5.4.1 Sourcing propagative material from pest free areas

The establishment and use of a pest free area by a NPPO provides assurance that specific pathogens are not present in the production area for plant products being exported. This facilitates entry into the importing country, for the commodity, without the need for an application of additional phytosanitary measures, when certain requirements are met.

Area freedom is a measure that might be applied to manage the risk posed by *Phytophthora* species associated with propagative material imported into Australia. The

requirements for establishing pest free areas or pest free places of production are set out in ISPM No. 4: *Establishment of pest free areas* (FAO 1995) and ISPM No. 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 1999).

Phytophthora ramorum has been detected in plants originating in an area in which, in accordance with the relevant ISPM No. 4, there is an official statement that *P. ramorum* does not occur (Sundheim et al. 2009); therefore, the department does not consider that imports based on pest free area or place of production declaration are a viable option.

5.4.2 Inspection and certification

The exporting country may be asked to inspect the shipment and certify that the shipment is free from regulated pests before export. This is a practical measure for visible pests or for pests which produce visible symptoms on plants. The importing country may specify that production of the commodity be undertaken under an officially monitored certification scheme to ensure stock is free from pests. This inspection is conducted in accordance with ISPM 23: *Guidelines for inspection*, which describes procedures for the inspection of consignments of plants, plant products and other regulated articles at import and export.

Phytosanitary certification is used to attest that consignments meet the phytosanitary requirements of the importing country and are conducted in accordance with ISPM 12: *Phytosanitary Certificates*. Phytosanitary certification contributes to the protection of plants, habitats and ecosystems in the importing countries. Phytosanitary certification also facilitates international trade in plants, plant products and other regulated articles by providing internationally agreed documentation and procedures.

Pre-export inspection and certification is not a suitable option to manage the risk posed by the importation of *Phytophthora* species host propagative material. Certain hosts may be infected but remain symptomless (Denman et al. 2008) and the assessment of the health of planting stock for quarantine certification is normally a visual process. Studies have demonstrated that sporangial production by both *P. ramorum* and *P. kernoviae* occurs on asymptomatic infected leaves and fruits of a range of hosts including *Crataegus*, *Laurus*, *Quercus*, *Rhododendron*, *Rosa* and *Smilax* species (Moralejo et al. 2007; Riedel et al. 2009). Visually healthy plants may harbour a sporulating pathogen in the roots; therefore, visual inspection alone may be inadequate.

Recent studies have demonstrated that both *P. ramorum* and *P. kernoviae* cause asymptomatic root infections in *Rhododendron* (Fichtner et al. 2011). The production of asymptomatic root infections by *P. ramorum* and *P. kernoviae* is of pivotal concern because such infections can be missed at the pre-export phytosanitary inspection. Asymptomatic root infections offer a hidden pathway of pathogen transmission via containerised nursery plants being distributed over large geographic areas. This is supported by the detection of *P. ramorum* in consignments that were visually inspected and certified by an exporting country as free from *P. ramorum* (Sundheim et al. 2009). For this reason, inspection and certification of propagative material from countries where these pathogens are known to occur is not considered an appropriate measure to mitigate the risk posed by *Phytophthora* species.

Standard nursery practices use prophylactic treatments with fungicides to suppress the occurrence of *Phytophthora* and other foliar fungal diseases; therefore, during pre-

export survey or inspection only *Phytophthora* species not affected by fungicides or that escaped fungicide applications will be detected. Additionally, species causing infections that are asymptomatic would likely be overlooked. The detection of *P. ramorum* in Norway in consignments that had previously been found free of the pathogen by at least two visual inspections at the place of production during official inspections support these assumptions (Sundheim et al. 2009). Therefore, visual inspection is not considered an appropriate measure to mitigate the risk posed by *Phytophthora* species under review.

5.4.3 Phytosanitary treatment for quarantinable pests

The importing country may specify chemical or physical treatments that must be applied to the consignment before it may be imported. The requirement or application of phytosanitary treatments to regulated articles is a phytosanitary measure used by contracting parties to prevent the introduction and spread of regulated pests. ISPM 28: *Phytosanitary treatments for regulated pests* provide guidelines on the use of treatments to manage pest risk.

Phytophthora species are, in general, difficult to control. Suppressive measures include sanitation, disinfection, and the use of fungicides and fumigants. Various treatments have been tested to determine efficacy in eradicating *P. ramorum* from infested plant material. No treatment can guarantee the removal of *P. ramorum* from consignments, with the exception of heat treatments (Garbelotto 2003; Swain et al. 2002; 2006; Aveskamp & Wingelaar 2005), which were considered an effective option for sanitising *P. ramorum* plant material; however, this kind of heat treatment can only be applied to non-living commodities. The use of fungicides may lower infection rates but will also reduce the efficacy of detection in consignments. These assumptions have been supported by the detection of *P. ramorum* in consignments that were treated to eradicate *P. ramorum* after the detection of symptoms. For this reason, the removal of *P. ramorum* from a consignment by a treatment is not considered an appropriate measure to mitigate the risk.

Fungicidal treatments in nursery stock against *Phytophthora* species with metalaxyl-M (Ridomil Gold Granulate), propamocarb (Previcur N) and fosetyl aluminium (Aliette 80 WG) are more effective as 'protectants' than as 'curatives', and they will not remove the pathogen from already infested plants (Tjosvold et al. 2005).

Heat treatments of propagative material may be used to remove *Phytophthora* species. However, studies indicate that *Phytophthora ramorum* can be highly heat tolerant as the fungus was isolated from infected material after keeping it at 55 degrees Celsius for up to one week (Harnik et al. 2004). The pathogen was then not recovered after two weeks at that temperature (Harnik et al. 2004). Wet heat (steam) is more effective than dry heat treatment. For example, aerated steam pasteurisation at 50 degrees Celsius or higher for 30 minutes eradicated *P. ramorum* as well as other pathogens from infested soil-free potting media and contaminated containers, without destroying the containers (Linderman & Davis 2006b).

Further studies indicated that a 30 minute dry heat treatment at 60 degrees Celsius was required to completely kill *P. ramorum* (Turner et al. 2006); however, after a 20 minute dry heat treatment at 55 degrees Celsius, *Camellia*, *Rhododendron* and *Viburnum* plants were completely killed. Therefore, this is not a viable option for nursery stock.

5.4.4 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 plants being required to have been produced from parent material that has been tested to be free of *P. ramorum*.

Since the identification of *P. ramorum* as the casual organism of sudden oak death, Australia restricted the importation of *P. ramorum* host propagative material from countries where this pathogen is known to occur to tissue cultures (microplantlets) and a small number as dormant cuttings and budwood. However, propagative material from countries where *P. ramorum* is not known to occur is allowed entry as tissue cultures and bare-rooted plants.

5.4.5 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.

Growth in PEQ of host propagative material can help avoid the introduction of *Phytophthora* species into the importing country. Imports of *Phytophthora* species host propagative material constitutes a high risk which justifies Australia's strict post-entry quarantine procedures. Therefore, it is suggested that imported propagative material must be grown in a closed government PEQ facility for visual observation of disease symptoms and pathogen screening, until the required pathogen screening/testing is completed.

6 Conclusion

The findings of this draft review of policy are based on a comprehensive analysis of the scientific literature. In addition to *Phytophthora ramorum*, this review considers the recently identified *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae*. This review updated the host list and assessed the biosecurity risks associated with the *Phytophthora* species under review. Based on this review, the department has proposed several changes to the existing host list of *Phytophthora ramorum*. The changes include the:

- addition of several new host genera to the natural host list of *Phytophthora ramorum*, and also for *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae*; and
- removal of experimental host genera from the regulated host list.

Based on this review, the department evaluated the appropriateness of the existing risk mitigation measures and proposes several changes to the existing policy. Major changes proposed to the existing policy are:

- reducing the PEQ growth period for cuttings and budwood from 24 months to 15 months with visual screening and active testing for all four *Phytophthora* species using molecular techniques including, but not limited to, PCR; and
- allowing the importation of bare-rooted plants. On arrival, the bare-rooted plants will be subjected to inspection, fumigation, culturing and molecular testing (generic *Phytophthora* PCR) to screen for *Phytophthora* species, and sodium hypochlorite treatment. This will be followed by 15 months growth in PEQ with visual inspection and molecular testing including, but not limited to, PCR.

The ultimate goal of Australia's phytosanitary measures is to protect plant health and prevent the introduction of identified quarantine pests and pathogens associated with plant propagative material. The department considers that the risk management measures proposed in this draft review of policy will be adequate to mitigate the risks posed by the *Phytophthora* species under review. The proposed risk management measures for *Phytophthora* species host propagative material from countries where *P. ramorum*, *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae* are known to occur are summarised below.

6.1 Tissue cultures

- Mandatory on-arrival inspection; and
- Growth in PEQ for a minimum 12 months with pathogen screening (visual inspection, culturing and molecular testing including, but not limited to, PCR).

6.2 Dormant cuttings and budwood (one-year-old only)

- Mandatory on-arrival inspection, fumigation and culturing to screen for *Phytophthora* species, molecular testing (generic *Phytophthora* PCR) and sodium hypochlorite treatment; and

- Growth in PEQ for 15 months with pathogen screening (visual inspection and molecular testing including, but not limited to, PCR).

6.3 Bare-rooted plants (one-year-old only)

- Mandatory on-arrival inspection, fumigation and culturing to screen for *Phytophthora* species, molecular testing (generic *Phytophthora* PCR) and sodium hypochlorite treatment; and
- Growth in PEQ for 15 months with pathogen screening (visual inspection and molecular testing including, but not limited to, PCR).

In the interim, some of the proposed changes have been adopted and the department's Import CONditions database (ICON) has been updated accordingly.

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

Unless specified, the hosts listed in the table are *P. ramorum* hosts. The host ranges of *P. ramorum*, *P. kernoviae*, *P. nemorosa* and *P. pseudosyringae* overlap and therefore, some of the hosts listed may also be susceptible to these other *Phytophthora* species. Some hosts are only known to be susceptible to *P. kernoviae*, *P. nemorosa* or *P. pseudosyringae* and this is indicated in the table. The geographical distribution of the natural hosts of *Phytophthora* species in the Australian environment is provided (source: Australia's Virtual Herbarium 2014, unless otherwise specified).

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
<i>Abies concolor</i> (Gordon & Glend.) Lindl. ex Hildebr. [Pinaceae] – White fir	<i>Picea concolor</i> Gordon	Cave et al. 2008; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Abies grandis</i> (Douglas ex D. Don) Lindl. [Pinaceae] – Grand fir	<i>Picea grandis</i> (Douglas ex D. Don) Loudon, <i>Abies grandis</i> (Douglas ex D. Don) Lindl. ssp. <i>idahoensis</i> (Silba) Silba, <i>Abies grandis</i> (Douglas ex D. Don) Lindl. var. <i>grandis</i> , <i>Abies grandis</i> (Douglas ex D. Don) Lindl. var. <i>idahoensis</i> Silba, <i>Abies grandis</i> (Douglas ex D. Don) Lindl. f. <i>johnsonii</i> O.V. Matthews), <i>Pinus grandis</i> Douglas ex D. Don (basionym)	Cave et al. 2008; Riley et al. 2011	VIC
<i>Abies magnifica</i> A. Murray [Pinaceae] – California red fir		Cave et al. 2008; Chastagner & Riley 2010	Recorded in Australia, but location not specified (Randall 2007)
<i>Abies procera</i> Rehder [Pinaceae] – Noble fir	<i>Abies nobilis</i> (Douglas ex D. Don) Lindl.	FERA 2012	TAS
<i>Acer circinatum</i> Pursh [Aceraceae] – Vine maple		COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Acer davidii</i> Franch. [Aceraceae] – Striped bark maple	<i>Acer grosseri</i> Pax, <i>Acer hersii</i> Rehder	Cave et al. 2008	VIC
<i>Acer laevigatum</i> Wall. [Aceraceae] – Evergreen maple	<i>Acer dimorphifolium</i> F. P. Metcalf, <i>Acer salweenense</i> W. W. Sm.	Cave et al. 2008	Recorded in Australia, but location not specified (Randall 2007)
<i>Acer macrophyllum</i> Pursh [Aceraceae] – Bigleaf maple		Scianna et al. 2003	Recorded in Australia, but location not specified (Randall 2007)
<i>Acer pseudoplatanus</i> L. [Aceraceae] – Sycamore maple		Cave et al. 2008	SA, NSW, VIC, TAS
<i>Adiantum jordanii</i> Mueller [Pteridaceae] – California maiden hair		Vettraino et al. 2006a	Not listed as occurring in Australia

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
<i>Adiantum pedatum</i> L. [Pteridaceae] – Northern Maidenhair Fern, Five-finger Fern	<i>Adiantum aleuticum</i> (Rupr.) C.A. Paris, <i>Adiantum boreale</i> C. Presl	Vettraino et al. 2006a	Recorded in Australia, but location not specified (Randall 2007)
<i>Aesculus californica</i> (Spach) Nutt. [Hippocastanaceae] – California buckeye	<i>Calothyrsus californica</i> Spach	Garbelotto et al. 2003; Scianna et al. 2003	Recorded in Australia, but location not specified (Randall 2007)
<i>Aesculus hippocastanum</i> L. [Hippocastanaceae] – Horse chestnut	<i>Aesculus hippocastanum</i> f. <i>memmingeri</i> (K. Koch) Schelle	Cave et al. 2008; Sansford et al. 2009	SA, NSW, ACT
<i>Alnus glutinosa</i> (L.) Gaertn. [Betulaceae] (L.) Lam.) – European alder (Note: Only reported as a host of <i>Phytophthora pseudosyringae</i>)	<i>Alnus barbata</i> C. A. Mey, <i>Alnus glutinosa</i> subsp. <i>barbata</i> (C. A. Mey.) Yalt., <i>Alnus glutinosa</i> var. <i>barbata</i> (C. A. Mey.) Ledeb., <i>Betula alnus</i> L., <i>Betula alnus</i> var. <i>glutinosa</i> L., <i>Betula glutinosa</i>	Jung et al. 2003	SA, NSW, ACT, TAS
<i>Annona cherimola</i> Mill. [Annonaceae] – Cherimoya, Custard apple (Note: Only reported as a host of <i>Phytophthora kernoviae</i>)	<i>Annona pubescens</i> Salisb., <i>Annona tripetala</i> Aiton	Ramsfield et al. 2009; EPPO 2013	Recorded in Australia, but location not specified (Randall 2007)
<i>Arbutus menziesii</i> Pursh [Aracaceae] – Madrone		Maloney et al. 2002	Recorded in Australia, but location not specified (Randall 2007)
<i>Arbutus unedo</i> L. [Aracaceae] – Strawberry tree		Sansford et al. 2009	ACT, SA, NSW, VIC, TAS, WA
<i>Arctostaphylos columbiana</i> Piper [Ericaceae] – Hairy manzanita	<i>Arctostaphylos columbiana</i> Piper var. <i>tracyi</i> Eastwood, <i>Arctostaphylos tracyi</i> (Eastwood) J.E. Adams ex McMinn	Sansford et al. 2009; Hansen et al. 2003a	Recorded in Australia, but location not specified (Randall 2007)
<i>Arctostaphylos manzanita</i> Parry [Ericaceae] – Whiteleaf manzanita		Garbelotto et al. 2003; Scianna et al. 2003; Cave et al. 2008	ACT
<i>Arctostaphylos uva-ursi</i> (L.) Spreng. [Ericaceae] – Kinnikinnick	<i>Arctostaphylos adenotricha</i> (Fernald & J.F. Macbr.) Á. Löve & D. Löve & Kapoor, <i>Arctostaphylos uva-ursi</i> (L.) Spreng. ssp. <i>adenotricha</i> (Fernald & J.F. Macbr.) Calder & Roy L. Taylor, <i>Arctostaphylos uva-ursi</i> (L.) Spreng. ssp. <i>coactilis</i> (Fernald & J.F. Macbr.) Á. Löve & D. Löve & Kapoor, <i>Arctostaphylos uva-ursi</i> (L.) Spreng. ssp. <i>longipilosa</i> Packer & Denford, <i>Arctostaphylos uva-ursi</i> (L.) Spreng. ssp. <i>monoensis</i> J.B. Roof, <i>Arctostaphylos uva-ursi</i> (L.) Spreng. ssp. <i>stipitata</i> Packer & Denford, <i>Arctostaphylos</i>	COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
	<i>uva-ursi</i> (L.) Spreng. var. <i>adenotricha</i> Fernald & J.F. Macbr., <i>Arctostaphylos uva-ursi</i> (L.) Spreng. var. <i>coactilis</i> Fernald & J.F. Macbr., <i>Arctostaphylos uva-ursi</i> (L.) Spreng. var. <i>leobreweri</i> J.B. Roof, <i>Arctostaphylos uva-ursi</i> (L.) Spreng. var. <i>marinensis</i> J.B. Roof, <i>Arctostaphylos uva-ursi</i> (L.) Spreng. var. <i>pacifica</i> Hultén, <i>Arctostaphylos uva-ursi</i> (L.) Spreng. var. <i>stipitata</i> (Packer & Denford) Dorn, <i>Arctostaphylos uva-ursi</i> (L.) Spreng. var. <i>suborbiculata</i> W. Knight)		
<i>Ardisia japonica</i> (Thunb.) Blume [Myrsinaceae] – Marberry, Ardisia	<i>Bladhia japonica</i> Thunb.	COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Berberis aquifolium</i> Pursh [Berberidaceae] – Holly leaved barberry, Oregon grape	<i>Berberis diversifolia</i> (Sweet) Steud, <i>Mahonia aquifolium</i> (Pursh) Nutt., <i>Mahonia aquifolium</i> subsp. <i>aquifolium</i> , <i>Mahonia diversifolia</i> Sweet	COMTF 2012	ACT, NSW, SA, TAS, VIC
<i>Berberis nervosa</i> Pursh [Berberidaceae] – Cascades mahonia, Creeping Oregon grape	<i>Mahonia nervosa</i> (Pursh) Nutt.	COMTF 2012	Not listed as occurring in Australia
<i>Betula pendula</i> Roth [Betulaceae] – European white birch	<i>Betula pendula</i> Roth f. <i>dalecarlica</i> (L. f.) C.K. Schneid, <i>Betula verrucosa</i>	COMTF 2012	TAS, ACT, VIC, NSW, SA
<i>Calluna vulgaris</i> (L.) Hull [Ericaceae] – Heather		Cave et al. 2008; Sansford et al. 2009; Orlikowski & Szkuta 2004	TAS, ACT, NSW, Qld
<i>Calycanthus occidentalis</i> Hook. & Arn. [Calycanthaceae] – Western sweetshrub		COMTF 2012	ACT, NSW, VIC
<i>Camellia japonica</i> L. [Theaceae] – Camellia	<i>Camellia hayaoi</i> Yanagita ex Kusaka, <i>Camellia japonica</i> var. <i>hortensis</i> (Makino) Makino, <i>Camellia japonica</i> var. <i>hozanensis</i> (Hayata) Yamam, <i>Camellia japonica</i> var. <i>macrocarpa</i> Masam, <i>Camellia japonica</i> var. <i>spontanea</i> (Makino) Makino, <i>Camellia rusticana</i> Honda, <i>Thea japonica</i> (L.) Baill)	Pintos Varela et al. 2003	ACT, VIC, NSW, SA
<i>Camellia</i> L. species [Theaceae] – Camellia (all species, hybrids and cultivars)		Pintos Varela et al. 2003; Beales et al. 2004a	Qld, VIC, ACT, NSW, SA
<i>Camellia reticulata</i> Lindl. [Theaceae] – Camellia	<i>Camellia heterophylla</i> Hu, <i>Camellia pitardii</i>	Parke et al. 2004b	Recorded in Australia, but location not

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
	var. <i>yunnanica</i> Sealy		specified (Randall 2007)
<i>Camellia sasanqua</i> Thunb. [Theaceae] – Camellia		Parke et al. 2004b	ACT, NSW
<i>Camellia</i> x <i>williamsii</i> W. W. Sm. [Theaceae] – Camellia hybrid		Parke et al. 2004b	Recorded in Australia, but location not specified (Randall 2007)
<i>Carpinus betulus</i> [Betulaceae] – Hornbeam (Note: Only reported as a host of <i>Phytophthora pseudosyringae</i>)	<i>Carpinus betulus</i> f. <i>pendula</i> (H. Massé) G. Kirchn, <i>Carpinus caucasica</i> Grossh.	Goheen & Frankel 2009; Denman et al. 2007	SA
<i>Castanea sativa</i> Mill. [Fagaceae] – European chestnut, Sweet chestnut	<i>Castanea vesca</i> Gaertn, <i>Castanea vulgaris</i> Lam., <i>Fagus castanea</i> L., <i>Fagus procera</i> Salisb.	Sansford et al. 2009; COMTF 2012	ACT, NSW, VIC, SA
<i>Castanopsis orthacantha</i> Franchet [Fagaceae]		Sansford et al. 2009	Not listed as occurring in Australia
<i>Ceanothus thyrsiflorus</i> Eschsch. [Rhamnaceae] – Blue blossom, Californian lilac		Cave et al. 2008; COMTF 2012	SA, ACT, NSW
<i>Cercis chinensis</i> Bunge [Fabaceae] – Chinese redbud		Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Chamaecyparis lawsoniana</i> (A. Murray) Parl. [Cupressaceae] – Lawson's cypress	<i>Cupressus lawsoniana</i> A. Murray	COMTF 2012; Brasier & Webber 2012	NSW, ACT, SA, TAS
<i>Choisya ternata</i> Kunth [Rutaceae] – Mexican-orange		COMTF 2012	ACT, SA, NSW, VIC
<i>Cinnamomum camphora</i> (L.) J.Presl [Lauraceae] – Camphor laurel	<i>Laurus camphora</i> L.	COMTF 2012; Sansford et al. 2009; Rooney-Latham et al. 2013	Qld, NSW, WA, VIC, ACT, SA
<i>Clintonia andrewsiana</i> Torr. [Liliaceae] – Andrew's clintonia bead lily		Cave et al. 2008; COMTF 2012	Not listed as occurring in Australia
<i>Cornus capitata</i> Wall. [Cornaceae] – Bentham's dogwood, Bentham's cornel	<i>Benthamia fragifera</i> Lindl., <i>Benthamidia capitata</i> (Wall.) H. Hara, <i>Dendrobenthamia capitata</i> (Wall.) Hutch.	Sansford et al. 2009; RAPRA 2012	VIC, NSW, ACT, TAS
<i>Cornus kousa</i> Hance [Cornaceae] – Chinese dogwood, Japanese dogwood	<i>Benthamia japonica</i> Siebold & Zucc., <i>Benthamidia japonica</i> (Siebold & Zucc.) H. Hara, <i>Cornus kousa</i> var. <i>chinensis</i> Osborn, <i>Dendrobenthamia japonica</i> var. <i>chinensis</i> (Osborn) W. P. Fang	COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Cornus kousa</i> x <i>Cornus capitata</i> [Cornaceae] –		Sansford et al. 2009; FERA 2012	n/a

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Norman haddon			
<i>Cornus</i> L. species [Cornaceae] – Cornel, Dogwood		RAPRA 2012	VIC, ACT, NSW, TAS
<i>Cornus nuttallii</i> Audubon [Cornaceae] - Mountain dogwood, Pacific dogwood, Western dogwood		COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Corylopsis spicata</i> Siebold & Zucc. [Hamamelidaceae] – Spike winter hazel		COMTF 2012	ACT, VIC
<i>Corylus cornuta</i> Marshall [Betulaceae] – California hazelnut	<i>Corylus rostrata</i> Aiton	Cave et al. 2008; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Cotoneaster</i> Medik. species [Rosaceae] (Note: <i>Cotoneaster horizontalis</i> and <i>C. dammeri</i> are reported as experimental hosts only (Bulajić et al. 2010))		FERA 2012	NSW, SA, ACT, VIC, TAS, Qld, WA
<i>Cydonia oblonga</i> Mill. [Rosaceae] – Quince	<i>Cydonia vulgaris</i> Pers., <i>Pyrus cydonia</i> L.	RAPRA 2012	SA, NSW, Qld, VIC, ACT, WA
<i>Daphniphyllum glaucescens</i> Blume [Daphniphyllaceae]		COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Distylium myricoides</i> Hemsl. [Hamamelidaceae] – Myrtle-leafed distylium		Cave et al. 2008	Recorded in Australia, but location not specified (Randall 2007)
<i>Drimys winteri</i> JR Forst. & G. Forst. [Winteraceae] – Winter's bark	<i>Drimys chilensis</i> DC., <i>Drimys winteri</i> var. <i>chilensis</i> (DC.) A. Gray	COMTF 2012	VIC
<i>Dryopteris arguta</i> (Kaulf.) Maxon [Dryopteridiaceae] – Californian wood fern, Coastal woodfern		COMTF 2012	Not listed as occurring in Australia
<i>Eucalyptus haemastoma</i> Sm. [Myrtaceae] – Scribbly gum		Sansford et al. 2009	NSW, ACT, VIC
<i>Euonymus kiautschovicus</i> Loes [Celastraceae] – Spreading euonymus, Creeping strawberry bush	<i>Euonymus patens</i> Rehder	Cave et al. 2008	Not listed as occurring in Australia
<i>Fagus sylvatica</i> L. [Fagaceae] – Beech	<i>Fagus moesiaca</i> (K. Malý) Czechtz, <i>Fagus orientalis</i> Lipsky, <i>Fagus sylvatica</i> var. <i>moesiaca</i> K. Malý	Sansford et al 2009; FERA 2012	NSW, SA, ACT, TAS, VIC

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
<i>Frangula californica</i> (Eschsch.) A. Gray [Rhamnaceae] – Californian coffeeberry, California buckthorn	<i>Rhamnus californica</i> Eschsch., <i>Rhamnus californica</i> subsp. <i>occidentalis</i> (JT Howell ex Greene) CB Wolf, <i>Rhamnus occidentalis</i> JT Howell ex Greene, <i>Rhamnus tomentella</i> Benth., <i>Frangula californica</i> (Eschsch.) A. Gray subsp. <i>tomentella</i> (Benth.) Kartesz & Gandhi, <i>Frangula californica</i> (Eschsch.) A. Gray subsp. <i>occidentalis</i> (JT Howell ex Greene) Kartesz & Gandhi	Goheen et al. 2006a; Garbelotto et al. 2003; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Frangula purshiana</i> (DC) JG Cooper [Rhamnaceae] – Cascara	<i>Rhamnus purshiana</i> DC.	Kliejunas 2003; Vettraino et al. 2006b	Recorded in Australia, but location not specified (Randall 2007)
<i>Fraxinus excelsior</i> L. [Oleaceae] – Ash	<i>Fraxinus excelsior</i> f. <i>aurea</i> (Pers.) Schelle, <i>Fraxinus excelsior</i> var. <i>aurea</i> Pers., <i>Fraxinus excelsior</i> f. <i>aureopendula</i> Rehder <i>Fraxinus excelsior</i> f. <i>diversifolia</i> (Aiton) Lingelsh., <i>Fraxinus excelsior</i> var. <i>diversifolia</i> Aiton, <i>Fraxinus excelsior</i> f. <i>pendula</i> (Aiton) Schelle, <i>Fraxinus excelsior</i> var. <i>pendula</i> Aiton	Cave et al. 2008; Sansford et al. 2009; COMTF 2012	ACT, VIC, TAS, NSW, Qld
<i>Fraxinus latifolia</i> Benth. [Oleaceae] – Oregon ash	<i>Fraxinus oregona</i> Nutt., <i>Fraxinus pennsylvanica</i> subsp. <i>oregona</i> (Nutt.) G. N. Mill.	COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Garrya elliptica</i> Douglas ex Lindl. [Garryaceae] – Silk tassel bush		Sansford et al. 2009	ACT, SA, NSW, TAS
<i>Gaultheria procumbens</i> L. [Ericaceae] – Wintergreen, Checkerberry		COMTF 2012; FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Gaultheria shallon</i> Pursh [Ericaceae] – Salal, Oregon wintergreen		Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Gevuina avellana</i> Molina [Proteaceae] – Chilean wildnut, Avellana (Note: Only reported as a host of <i>Phytophthora kernoviae</i>)		Hughes et al. 2005	NSW
<i>Griselinia littoralis</i> (Raoul) Raoul [Cornaceae] – New Zealand privet	<i>Pukateria littoralis</i> Raoul	Giltrap et al. 2007; COMTF 2012	TAS, NSW, VIC
<i>Hamamelis</i> × <i>intermedia</i> Rehder [Hamamelidaceae] (<i>H. mollis</i> × <i>H. japonica</i>) –		Sansford et al. 2009	VIC

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Hybrid witch hazel			
<i>Hamamelis mollis</i> Oliv.[Hamamelidaceae] – Chinese witch hazel		COMTF 2012	ACT
<i>Hamamelis virginiana</i> L. [Hamamelidaceae]– Virginian witch hazel	<i>Hamamelis macrophylla</i> Pursh, <i>Hamamelis mexicana</i> Standl.	Giltrap et al. 2004	VIC
<i>Heteromeles arbutifolia</i> (Lindl.) M. Roem. [Rosaceae]– California holly, Toyon, Christmasberry	<i>Heteromeles salicifolia</i> (C. Presl) Abrams, <i>Photinia arbutifolia</i> Lindl., <i>Photinia salicifolia</i> C. Presl	Garbelotto et al. 2003; Kliejunas 2003	SA
<i>Hydrangea seemannii</i> L. Riley [Hydrangeaceae] – Hydrangea		FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Ilex aquifolium</i> L [Aquifoliaceae] – European holly		COMTF 2012	SA, NSW, TAS, VIC, ACT
<i>Ilex latifolia</i> Thunb. [Aquifoliaceae]– Tarajo holly	<i>Ilex macrophylla</i> Blume	COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Ilex purpurea</i> Hassk [Aquifoliaceae] – Oriental holly	<i>Ilex oldhamii</i> Miq., <i>Ilex purpurea</i> var. <i>oldhamii</i> (Miq.) Loes.	FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Illicium parviflorum</i> Michx. ex Vent. [Schisandraceae] – Swamp star anise, Yellow anise	<i>Badianifera parviflora</i> (Michx. ex Vent.) Kuntze	COMTF 2012	NSW
<i>Kalmia angustifolia</i> L. [Ericaceae] – Sheep laurel	<i>Kalmia carolina</i> Small, <i>Kalmia intermedia</i> Lange, <i>Kalmia angustifolia</i> L. var. <i>carolina</i> (Small) Fernald	Sansford et al. 2009	ACT
<i>Kalmia</i> L. species [Ericaceae] – Laurel		FERA 2012	ACT, SA
<i>Kalmia latifolia</i> L. [Ericaceae]– Mountain laurel	<i>Kalmia latifolia</i> f. <i>myrtifolia</i> (Bosse) K. Koch, <i>Kalmia latifolia</i> var. <i>myrtifolia</i> Bosse	Sansford et al. 2009	SA
<i>Larix decidua</i> Mill. [Pinaceae]– European larch	<i>Larix europaea</i> DC., <i>Pinus larix</i> L.	COMTF 2012; EPPO 2011; FERA 2012	TAS
<i>Larix kaempferi</i> (Lamb.) Carrière [Pinaceae] – Japanese larch, Larch	<i>Abies leptolepis</i> Siebold & Zucc., <i>Larix japonica</i> Carrière, <i>Larix kaempferi</i> var. <i>pendula</i> (Beissn.) C. K. Schneid., <i>Larix leptolepis</i> (Siebold & Zucc.) Gordon, <i>Larix leptolepis</i> var. <i>murrayana</i> Maxim, <i>Larix</i>	Webber et al. 2010a, b; FERA 2012	ACT, NSW

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
	<i>leptolepis</i> f. <i>pendula</i> (Beissn.) Rehder, <i>Larix leptolepis</i> var. <i>pendula</i> Beissn., <i>Pinus kaempferi</i> Lamb., <i>Pseudolarix kaempferi</i> (Lamb.) Gordon		
<i>Larix x marschlinii</i> Coaz [Pinaceae] – Hybrid larch	<i>Larix x eurolepis</i> A. Henry	FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Laurus nobilis</i> L. [Lauraceae] – Bay laurel		COMTF 2012	VIC, SA, ACT, TAS, NSW
<i>Leucothoe axillaris</i> (Lam.) D. Don [Ericaceae] – Fetter-bush, Dog hobble	<i>Andromeda axillaris</i> Lam., <i>Andromeda catesbaei</i> Walter, <i>Andromeda walteri</i> Willd., <i>Leucothoe catesbaei</i> (Walter) A. Gray	Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Leucothoe fontanesiana</i> (Steud.) Sleumer [Ericaceae] – Drooping leucothoe	<i>Leucothoe walteri</i> N. C. Melvin	Sansford et al. 2009	NSW, VIC
<i>Liriodendron tulipifera</i> L. [Magnoliaceae] – Tulip tree	<i>Liriodendron tulipifera</i> f. <i>aureomarginatum</i> (Dippel) Schelle, <i>Liriodendron tulipifera</i> f. <i>integrifolium</i> (G. Kirchn.	Hughes et al. 2005	ACT, SA, NSW, TAS
<i>Lithocarpus glaber</i> (Thunb.) Nakai [Fagaceae] – Japanese oak	<i>Pasania glabra</i> (Thunb.) Oerst., <i>Quercus glabra</i> Thunb.	COMTF 2012	VIC
<i>Lonicera hispidula</i> (Lindl.) Douglas ex Torr. & A. Gray [Caprifoliaceae] – Californian honeysuckle	<i>Lonicera hispidula</i> var. <i>vacillans</i> A. Gray	Garbelotto et al. 2003; Goheen et al. 2006a; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Lonicera periclymenum</i> L. [Caprifoliaceae] – Honeysuckle, Woodbine		Sansford et al. 2009	Qld, NSW, TAS
<i>Loropetalum chinense</i> (R. Br.) Oliv. [Hamamelidaceae] – Loropetalum	<i>Hamamelis chinensis</i> R. Br., <i>Loropetalum chinense</i> (R. Br.) Oliv. var. <i>chinense</i> , <i>Loropetalum chinense</i> (R. Br.) Oliv. var. <i>rubrum</i> Yieh	Blomquist et al. 2012	ACT, NSW, VIC
<i>Magnolia acuminata</i> (L.) L. [Magnoliaceae] – Blue magnolia, Cucumber-tree, Yellow cucumber-tree	<i>Magnolia cordata</i> Michx., <i>Magnolia virginiana</i> L. var. <i>acuminata</i> L., <i>Magnolia acuminata</i> (L.) L. var. <i>acuminata</i>	FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Magnolia acuminata x brooklynensis</i> [Magnoliaceae] – 'Yellow bird'		RAPRA 2012	n/a
<i>Magnolia delavayi</i> Franch [Magnoliaceae] – Chinese Magnolia		FERA 2012	VIC

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
<i>Magnolia denudata</i> Desr. [Magnoliaceae] – Lily Tree	<i>Magnolia conspicua</i> Salisb., <i>Magnolia yulan</i> Desf.	Sansford et al. 2009	VIC
<i>Magnolia denudata</i> x <i>salicifolia</i> [Magnoliaceae] – Magnolia hybrid		Sansford et al. 2009	n/a
<i>Magnolia doltsopa</i> (Buch.-Ham. ex DC.) Figlar [Magnoliaceae]– Michelia	<i>Magnolia excelsa</i> Wall., <i>Michelia doltsopa</i> Buch.-Ham. ex DC, <i>Michelia excelsa</i> (Wall.) Blume	Sansford et al. 2009; COMTF 2012	Not listed as occurring in Australia
<i>Magnolia ernestii</i> Figlar [Magnoliaceae] – Michelia	<i>Michelia sinensis</i> Hemsl. & E. H. Wilson, <i>Michelia wilsonii</i> Finet & Gagnep	Sansford et al. 2009	Not listed as occurring in Australia
<i>Magnolia figo</i> (Lour.) DC. [Magnoliaceae] – Banana magnolia, Banana shrub	<i>Liriodendron figo</i> Lour., <i>Magnolia fuscata</i> Andrews, <i>Michelia figo</i> (Lour.) Spreng., <i>Michelia fuscata</i> (Andrews) Blume	APHIS 2008a	Not listed as occurring in Australia
<i>Magnolia foveolata</i> (Merr. ex Dandy) Figlar [Magnoliaceae]	<i>Michelia foveolata</i> Merr. ex Dandy	Sansford et al. 2009; COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Magnolia grandiflora</i> L. [Magnoliaceae] – Magnolia	<i>Magnolia foetida</i> (L.) Sarg., <i>Magnolia grandiflora</i> var. <i>exoniensis</i> hort. ex Loudon, <i>Magnolia grandiflora</i> f. <i>lanceolata</i> (Aiton) Rehder	Sansford et al. 2009	NSW, Qld, SA, VIC
<i>Magnolia kobus</i> DC. [Magnoliaceae] – Kobus magnolia	<i>Magnolia kobus</i> var. <i>borealis</i> Sarg., <i>Magnolia kobus</i> DC. var. <i>kobus</i>	Sansford et al. 2009	NSW
<i>Magnolia liliiflora</i> Desr. [Magnoliaceae] – Purple magnolia		APHIS 2008b; COMTF 2012	VIC
<i>Magnolia salicifolia</i> (Siebold & Zucc.) Maxim. [Magnoliaceae] – Anise magnolia	<i>Buergeria salicifolia</i> Siebold & Zucc., <i>Magnolia</i> × <i>proctoriana</i> Rehder	Sansford et al. 2009	VIC
<i>Magnolia stellata</i> (Siebold & Zucc.) Maxim. [Magnoliaceae] – Star magnolia	<i>Magnolia kobus</i> var. <i>stellata</i> (Siebold & Zucc.) Blackburn, <i>Magnolia stellata</i> var. <i>rosea</i> J. H. Veitch	Giltrap et al. 2007; Sansford et al. 2009	NSW
<i>Magnolia</i> x <i>kewensis</i> Pearce nom. inval. [Magnoliaceae]		RAPRA 2012	Not listed as occurring in Australia
<i>Magnolia</i> x <i>loebneri</i> Kache [Magnoliaceae]– Loebner magnolia		Giltrap et al. 2007; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
<i>Magnolia x soulangeana</i> Soul.-Bod. [Magnoliaceae] – Saucer magnolia		COMTF 2012	ACT, SA
<i>Magnolia x thompsoniana</i> de Vos [Magnoliaceae]		COMTF 2012; RAPRA 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Maianthemum racemosum</i> (L.) Link [Liliaceae] – False Solomon's seal	<i>Convallaria racemosa</i> L., <i>Smilacina racemosa</i> (L.) Desf, <i>Vagnera racemosa</i> (L.) Morong	Hüberli et al. 2005	Recorded in Australia, but location not specified (Randall 2007)
<i>Malus pumila</i> Mill [Rosaceae]– Paradise apple (Note: Only reported as a host of <i>Phytophthora pseudosyringae</i>)	<i>Malus dasyphylla</i> Borkh., <i>Malus niedzwetzkyana</i> Dieck, <i>Malus paradisiaca</i> (L.) Medik., <i>Malus praecox</i> Borkh., <i>Malus pumila</i> var. <i>niedzwetzkyana</i> (Dieck) C. K. Schneid., <i>Malus pumila</i> var. <i>paradisiaca</i> (L.) C. K. Schneid., <i>Malus sylvestris</i> var. <i>dasyphylla</i> (Borkh.) Ponomar., <i>Malus sylvestris</i> var. <i>niedzwetskyana</i> (Dieck) L. H. Bailey, <i>Malus sylvestris</i> var. <i>praecox</i> Ponomar., <i>Pyrus malus</i> subsp. <i>paradisiaca</i> (L.) Schübl. & G. Martens, <i>Pyrus malus</i> var. <i>paradisiaca</i> L., <i>Pyrus niedzwetzkyana</i> (Dieck) Hemsl., <i>Pyrus praecox</i> Pall.	Sansford 2012	SA, VIC, NSW, Qld, ACT, TAS, WA
<i>Manglietia insignis</i> (Wall.) Blume [Magnoliaceae] – Red lotus tree	<i>Magnolia insignis</i> Wall.	Cave et al. 2008; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Michelia cavaleri</i> [Magnoliaceae] – Michelia		Sansford et al. 2009	Not listed as occurring in Australia
<i>Michelia maudiae</i> Dunn [Magnoliaceae] – Michelia	<i>Michelia chingii</i> W.C. Cheng	Sansford et al. 2009	VIC
<i>Molinadendron sinaloense</i> (Standl. & Gentry) P.K. Endress [Hamamelidaceae]	<i>Distylium sinaloense</i> Standl. & Gentry	COMTF 2012	Not listed as occurring in Australia
<i>Myristica fragrans</i> Houtt. [Myristicaceae]– Nutmeg	<i>Myristica officinalis</i> L.	Mathew & Beena 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Nerium oleander</i> L. [Apocynaceae] – Oleander	<i>Nerium indicum</i> Mill., <i>Nerium odorum</i> Aiton	COMTF 2012	WA, SA, Qld, NSW, ACT, VIC, TAS
<i>Nothofagus alpina</i> (Poepp. & Endl.) Oerst. [Fagaceae] – Rauli beech	<i>Fagus alpina</i> Poepp. & Endl, <i>Fagus nervosa</i> Phil., <i>Fagus procera</i> Poepp. & Endl., <i>Lophozonia alpina</i> (Poepp. & Endl.) Heenan & Smissen, <i>Nothofagus nervosa</i> (Phil.)	Scanu et al. 2012	Recorded in Australia, but location not specified (Randall 2007)

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
	Krasser, <i>Nothofagus procera</i> Oerst.		
<i>Nothofagus obliqua</i> (Mirb.) Blume [Fagaceae] – Roble beech	<i>Fagus obliqua</i> Mirb.	Sansford et al. 2009	VIC
<i>Notholithocarpus densiflorus</i> (Hook. & Arn.) Manos et al. [Fagaceae]– Tanoak	<i>Lithocarpus densiflorus</i> (Hook. & Arn.) Rehder, <i>Quercus densiflora</i> Hook. & Arn.	Garbelotto et al. 2003; Hansen et al. 2003a; Scianna et al. 2003; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Osmanthus decorus</i> (Boiss. & Balansa) Kasapligil [Oleaceae]– Osmanthus	<i>Phillyrea decora</i> Boiss. & Balansa	Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Osmanthus delavayi</i> Franch. [Oleaceae] – Delavay osmanthus	<i>Siphonosmanthus delavayi</i> (Franch.) Stapf	Cave et al. 2008; RAPRA 2012; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Osmanthus fragrans</i> Lour. [Oleaceae] – Sweet olive	<i>Osmanthus aurantiacus</i> (Makino) Nakai	Cave et al. 2008; Grünwald et al. 2008a; Sansford et al. 2009	NSW
<i>Osmanthus heterophyllus</i> (G. Don) P. S. Green [Oleaceae] – Holly osmanthus, Holly olive	<i>Ilex heterophylla</i> G. Don, <i>Olea aquifolium</i> Siebold & Zucc., <i>Olea ilicifolia</i> Siebold ex Hassk., <i>Osmanthus ilicifolius</i> (Hassk.) hort. ex Carrière	Grünwald et al. 2008a; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Osmorhiza berteroi</i> DC. [Apiaceae] – Sweet cicely	<i>Osmorhiza chilensis</i> Hook. & Arn., <i>Scandix chilensis</i> Molina	Sansford et al. 2009	Not listed as occurring in Australia
<i>Parakilometerseria lotungensis</i> (Chun & C.H. Tsoong) Y.W. Law [Magnoliaceae] – Eastern joy lotus tree	<i>Magnolia lotungensis</i> Chun & C.H. Tsoong	Sansford et al. 2009	Not listed as occurring in Australia
<i>Parrotia persica</i> (DC.) C. A. Mey. [Hamamelidaceae] – Persian Ironwood		Hughes et al. 2006; Sansford et al. 2009	ACT, NSW, VIC
<i>Phoradendron serotinum</i> subsp. <i>macrophyllum</i> (Engelm.) Kuijt [Santalaceae] – Mistletoe		Riley & Chastagner 2011	Not listed as occurring in Australia
<i>Photinia x fraseri</i> Dress [Rosaceae] – Fraser’s photinia		Sansford et al. 2009; Orlikowski & Szkuta 2004	Recorded in Australia, but location not specified (Randall 2007)
<i>Physocarpus opulifolius</i> (L.) Maxim. [Rosaceae] – Ninebark	<i>Opulaster intermedius</i> Rydb., <i>Physocarpus intermedius</i> (Rydb.) C. K. Schneid., <i>Physocarpus stellatus</i> (Rydb. ex Small) Rehder	COMTF 2012	ACT, NSW
<i>Picea sitchensis</i> (Bong.) Carrière [Pinaceae] –		COMTF 2012; FERA 2012	NSW, SA

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Sitka spruce			
<i>Pieris floribunda</i> (Pursh) Benth. & Hook. f. [Ericaceae] – Flutterbush, Mountain-andromeda		Sansford 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Pieris floribunda</i> x <i>japonica</i> [Ericaceae] – Mountain andromeda, <i>Pieris</i> x 'Brouwer's Beauty'		Kliejunas 2003; Parke et al. 2004a, b	n/a
<i>Pieris formosa</i> (Wall.) D. Don [Ericaceae] – Himalaya andromeda	<i>Andromeda formosa</i> Wall., <i>Pieris formosa</i> var. <i>forrestii</i> Airy Shaw, <i>Pieris forrestii</i> R. L. Harrow	Kliejunas 2003; Inman et al. 2003	Recorded in Australia, but location not specified (Randall 2007)
<i>Pieris japonica</i> (Thunb.) D. Don ex G. Don [Ericaceae] – Japanese pieris	<i>Andromeda japonica</i> Thunb., <i>Pieris taiwanensis</i> Hayata	Parke et al. 2004a, b; Husson et al. 2007	Recorded in Australia, but location not specified (Randall 2007)
<i>Pieris japonica</i> x <i>formosa</i> [Ericaceae] – Ornamental pieris		Parke et al. 2004b; Sansford et al. 2009	n/a
<i>Pinus radiata</i> D. Don [Pinaceae] – Monterey pine	<i>Pinus insignis</i> Douglas ex Loudon	Dick et al. 2014	NSW, VIC, Qld, SA, WA, ACT, TAS
<i>Pittosporum undulatum</i> Vent. [Pittosporaceae] – Victorian box		Hüberli et al. 2006; Sansford et al. 2009	NSW, VIC, Qld, SA, WA, ACT, TAS, NT
<i>Prumnopitys ferruginea</i> (G. Benn. Ex D. Don) de Laub. [Podocarpaceae]		Dick et al. 2014	Recorded in Australia, but location not specified (Randall 2007)
<i>Prunus laurocerasus</i> L. [Rosaceae] – Dwarf English laurel	<i>Cerasus laurocerasus</i> (L.) Loisel., <i>Laurocerasus officinalis</i> M. Roem., <i>Laurocerasus ottinii</i> Carrière, <i>Laurocerasus vulgaris</i> Carrière, <i>Prunus grandifolia</i> Salisb.	Cave et al. 2008; Sansford et al. 2009	NSW, SA, VIC, TAS
<i>Prunus lusitanica</i> L. [Rosaceae] – Portuguese laurel cherry	<i>Laurocerasus lusitanica</i> (L.) M. Roem	Sansford et al. 2009	NSW, VIC, ACT, SA, TAS
<i>Pseudotsuga menziesii</i> (Mirb.) Franco [Pinaceae] – Douglas fir	<i>Abies menziesii</i> Mirb., <i>Abies mucronata</i> Raf., <i>Abies taxifolia</i> Poir., <i>Pinus douglasii</i> Sabine ex D. Don, <i>Pinus taxifolia</i> Lamb., <i>Pseudotsuga douglasii</i> (Sabine ex D. Don) Carrière, <i>Pseudotsuga mucronata</i> (Raf.) Sudw., <i>Pseudotsuga taxifolia</i> Britton	Davidson et al. 2002c	SA, NSW, TAS, ACT
<i>Pyracantha koidzumii</i> (Hayata) Rehder [Rosaceae] – Formosa firethorn	<i>Cotoneaster koidzumii</i> Hayata	Briere et al. 2005; Sansford et al. 2009	SA

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
<i>Quercus acuta</i> Thunb. [Fagaceae] – Japanese evergreen oak		COMTF 2012	VIC
<i>Quercus agrifolia</i> Née [Fagaceae] – Coast live oak		Hansen et al. 2003a; Garbelotto et al. 2003; Scianna et al. 2003; Vettraino et al. 2008	ACT
<i>Quercus cerris</i> L. [Fagaceae] – Turkey oak		Sansford et al. 2009; COMTF 2012	NSW, ACT, SA, VIC
<i>Quercus chrysolepis</i> Liebm. [Fagaceae] – Canyon live oak		Murphy & Rizzo 2003	ACT
<i>Quercus falcata</i> Michx. [Fagaceae] – Southern red oak		Brasier et al. 2004a	Recorded in Australia, but location not specified (Randall 2007)
<i>Quercus ilex</i> L. [Fagaceae] – Holm oak	<i>Quercus ballota</i> Desf., <i>Quercus gramuntia</i> L., <i>Quercus rotundifolia</i> Lam.	Denman et al. 2005	SA, ACT, NSW, TAS
<i>Quercus kelloggii</i> Newb. [Fagaceae] – Californian black oak		Garbelotto et al. 2003; Scianna et al. 2003; Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Quercus</i> L. species [Fagaceae] – Beech		COMTF 2012	SA, ACT, NSW, VIC, TAS, Qld
<i>Quercus petraea</i> (Matt.) Liebl. [Fagaceae] – Sessile oak	<i>Quercus iberica</i> Steven ex M. Bieb., <i>Quercus sessiliflora</i> Salisb	COMTF 2012	NSW
<i>Quercus phillyraeoides</i> A. Gray [Fagaceae] – Ubame oak	<i>Quercus wrightii</i> Nakai	FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Quercus robur</i> L. [Fagaceae] – English oak, Pedunculate oak	<i>Quercus brutia</i> Ten., <i>Quercus haas</i> Kotschy, <i>Quercus imeretina</i> Steven ex Woronow, <i>Quercus longipes</i> Steven, <i>Quercus pedunculata</i> Ehrh., <i>Quercus pedunculiflora</i> K. Koch, <i>Quercus pendulina</i> Kit., <i>Quercus thomasi</i> Ten.	FERA 2012	SA, ACT, NSW, TAS, Qld, VIC
<i>Quercus rubra</i> L. [Fagaceae] – Northern red oak	<i>Quercus borealis</i> F. Michx.	Sundheim et al. 2009	ACT
<i>Quercus wislizeni</i> A. DC. [Fagaceae] – Shreve oak	<i>Quercus parvula</i> Greene, <i>Quercus parvula</i> var. <i>shrevei</i> (C.H. Mull.) Nixon	Garbelotto et al. 2003; Scianna et al. 2003	Recorded in Australia, but location not specified (Randall 2007)
<i>Rhododendron catawbiense</i> Michx. [Ericaceae] – Catawba rhododendron		Herrero et al. 2006	NSW
<i>Rhododendron</i> L. species [Ericaceae] –		Garbelotto et al. 2003; Parke et al.	Qld, ACT, NSW, TAS, VIC, SA, WA

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
Rhododendron		2004a; Tjosvold et al. 2005; Cave et al. 2008; Tsopelas et al. 2011; Dick et al. 2014	
<i>Rhododendron macrophyllum</i> D. Don ex G. Don [Ericaceae] – California rose bay	<i>Rhododendron californicum</i> Hook.	Scianna et al. 2003; Goheen et al. 2002	Recorded in Australia, but location not specified (Randall 2007)
<i>Rhododendron ponticum</i> L. [Ericaceae] – Common rhododendron		Purse et al. 2013	TAS, NSW, SA
<i>Ribes laurifolium</i> Jancz. [Grossulariaceae] – Bayleaf currant		COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Rosa gymnocarpa</i> Nutt. [Rosaceae] – Californian wood rose		Hüberli et al. 2004	Recorded in Australia, but location not specified (Randall 2007)
<i>Rosa rugosa</i> Thunb. [Rosaceae] – Rugosa rose		Sansford et al. 2009	SA
<i>Rosa</i> species (several different cultivars) [Rosaceae] – Rose		Cave et al. 2008; Sansford et al. 2009	SA, NSW, VIC, Qld, TAS, WA, ACT
<i>Rubus spectabilis</i> Pursh [Rosaceae] – Salmonberry		Cave et al. 2008	Recorded in Australia, but location not specified (Randall 2007)
<i>Salix caprea</i> L. [Salicaceae] – Goat willow, Sallow		Sansford et al. 2009; COMTF 2012	TAS, NSW, ACT, VIC
<i>Sarcococca hookeriana</i> Baill. var. <i>digyna</i> Franch. [Buxaceae] – Himalyan sweet box	<i>Sarcococca humilis</i> Stapf	FERA 2012; Alexandra Schlenzig, SASA, personal communication 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Schima superba</i> Gardner & Champ. [Theaceae] – Chinese guger tree	<i>Schima argentea</i> E. Pritz., <i>Schima liukiuensis</i> Nakai	Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Schima wallichii</i> (DC.) Korth. [Theaceae]	<i>Gordonia wallichii</i> DC., <i>Schima crenata</i> Korth., <i>Schima noronhae</i> Reinw. ex Blume	COMTF 2012	NSW
<i>Sequoia</i> Endl. species [Taxodiaceae] – Redwood		Scianna et al. 2003	ACT, SA, VIC, TAS, WA
<i>Sequoia sempervirens</i> (D. Don) Endl. [Taxodiaceae] – Coast redwood	<i>Taxodium sempervirens</i> D. Don	Maloney et al. 2002; Kliejunas 2003; Hansen et al. 2003a	ACT, VIC, SA, TAS, WA
<i>Syringa vulgaris</i> L. [Oleaceae] – Lilac		Beales et al. 2004b	ACT, WA, NSW, TAS
<i>Taxus baccata</i> L. [Taxaceae] – Yew	<i>Taxus fastigiata</i> Lindl.	Lane et al. 2004	NSW, SA, TAS, ACT
<i>Taxus brevifolia</i> Nutt. [Taxaceae] – Pacific yew		Sansford et al. 2009; COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
<i>Taxus x media</i> Rehder [Taxaceae] – Anglojap yew		Sansford et al. 2009	Recorded in Australia, but location not specified (Randall 2007)
<i>Torreya californica</i> Torr. [Taxaceae] – California nutmeg	<i>Tumion californicum</i> (Torr.) Greene	Cave et al. 2008; Sansford et al. 2009; COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Toxicodendron diversilobum</i> (Torr. & A. Gray) Greene [Anacardiaceae] – Pacific poison oak	<i>Rhus diversiloba</i> Torr. & A. Gray	Cave et al. 2008	Qld
<i>Trachelospermum jasminoides</i> (Lindl.) Lem. [Apocynaceae] – Star jasmine, Confederate jasmine		COMTF 2012	Qld, NSW, ACT
<i>Trientalis latifolia</i> Hook. [Primulaceae] – Western star flower		Hüberli et al. 2003b	Not listed as occurring in Australia
<i>Tsuga heterophylla</i> (Raf.) Sarg. [Pinaceae] – Western hemlock	<i>Abies albertiana</i> A. Murray, <i>Abies heterophylla</i> Raf., <i>Tsuga jeffreyi</i> (A. Henry) A. Henry	COMTF 2012; FERA 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Umbellularia californica</i> (Hook. & Arn.) Nutt. [Lauraceae] – Californian bay laurel	<i>Tetranthera californica</i> Hook. & Arn.	Garbelotto et al. 2003; Scianna et al. 2003; Hansen et al. 2003a	SA
<i>Vaccinium myrtillus</i> L. [Ericaceae] – Bilberry	<i>Vaccinium yatabei</i> Makino	Herrero et al. 2011	Recorded in Australia, but location not specified (Randall 2007)
<i>Vaccinium ovatum</i> Pursh [Ericaceae] – Californian huckleberry		Goheen et al. 2002; Davidson et al. 2003b; Scianna et al. 2003	VIC
<i>Vaccinium vitis-idaea</i> L. [Ericaceae] – Cowberry		COMTF 2012	Recorded in Australia, but location not specified (Randall 2007)
<i>Vaccinium x intermedium</i> Ruthe [Ericaceae]		FERA 2012	Not listed as occurring in Australia
<i>Vancouveria planipetala</i> Calloni [Berberidaceae] – Redwood ivy		COMTF 2012	Not listed as occurring in Australia
<i>Veronica spicata</i> L. [Scrophulariaceae] – Spiked speedwell	<i>Pseudolysimachion spicatum</i> (L.) Opiz, <i>Veronica barrelieri</i> Schult., <i>Veronica hololeuca</i> Juz., <i>Veronica orchidea</i> Crantz	COMTF 2012; APHIS 2012	NSW
<i>Viburnum carlcephalum</i> x <i>Viburnum utile</i> [Caprifoliaceae] – Viburnum hybrid		Osterbauer 2004	n/a
<i>Viburnum davidii</i> Franch. [Caprifoliaceae] –		Osterbauer 2004	ACT

Scientific name/common name(s)	Synonym(s)	Reference	Presence in Australia
David viburnum			
<i>Viburnum farreri</i> Stearn [Caprifoliaceae] – Fragrant viburnum	<i>Viburnum fragrans</i> Bunge, <i>Viburnum fragrans</i> var. <i>nanus</i> Boom	Osterbauer 2004	Recorded in Australia, but location not specified (Randall 2007)
<i>Viburnum</i> L. species [Caprifoliaceae] –Viburnum		Parke et al. 2004a, b; Tjosvold et al. 2005; Cave et al. 2008; Sansford et al. 2009; COMTF 2012; RAPRA 2012	SA, ACT, VIC, NSW, TAS
<i>Viburnum lantana</i> L. [Caprifoliaceae] – Wayfaringtree viburnum		Osterbauer 2004	NSW
<i>Viburnum opulus</i> L. [Caprifoliaceae]– European cranberry, Bush viburnum	<i>Viburnum opulus</i> var. <i>calvescens</i> (Rehder) H. Hara, <i>Viburnum opulus</i> f. <i>nanum</i> (I. David) Zabel, <i>Viburnum opulus</i> f. <i>xanthocarpum</i> (Endl.) Rehder, <i>Viburnum sargentii</i> Koehne, <i>Viburnum sargentii</i> f. <i>calvescens</i> (Rehder) Rehder, <i>Viburnum sargentii</i> var. <i>calvescens</i> Rehder, <i>Viburnum sargentii</i> var. <i>flavum</i> Rehder, <i>Viburnum sargentii</i> f. <i>puberulum</i> Kom., <i>Viburnum trilobum</i> Marshall	Osterbauer 2004	NSW, TAS, VIC
<i>Viburnum plicatum</i> Thunb. var. <i>tomentosum</i> Miq. [Caprifoliaceae] – Doublefile viburnum	<i>Viburnum plicatum</i> f. <i>mariesii</i> (Veitch) Rehder, <i>Viburnum plicatum</i> f. <i>tomentosum</i> (Miq.) Rehder, <i>Viburnum tomentosum</i> Thunb, <i>Viburnum tomentosum</i> var. <i>mariesii</i> J. H. Veitch	Osterbauer 2004	Recorded in Australia, but location not specified (Randall 2007)
<i>Viburnum tinus</i> L. [Caprifoliaceae] – Laurustinus	<i>Viburnum lucidum</i> Mill, <i>Viburnum tinus</i> var. <i>hirtum</i> Aiton, <i>Viburnum tinus</i> var. <i>lucidum</i> (Mill.) Aiton	Vettraino et al. 2009	SA, ACT, VIC, TAS, NSW
<i>Viburnum x bodnantense</i> Aberc. [Caprifoliaceae] – Viburnum		De Merlier et al. 2003	Recorded in Australia, but location not specified (Randall 2007)
<i>Viburnum x burkwoodii</i> Burkwood & Skipwith [Caprifoliaceae] – Burkwood viburnum	<i>Viburnum</i> × <i>chenaultii</i> Chenault	Osterbauer 2004	Recorded in Australia, but location not specified (Randall 2007)
<i>Viburnum x pragnense</i> [Caprifoliaceae] – Prague viburnum		Osterbauer 2004	Not listed as occurring in Australia

Appendix B: Additional quarantine pest data

Quarantine pest	<i>Phytophthora kernoviae</i> 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	<i>Phytophthora nemorosa</i> 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	<i>Phytophthora pseudosyringae</i> 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	<i>Phytophthora ramorum</i> 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, <i>P. ramorum</i> 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 <i>P. ramorum</i> 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 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 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 of Agriculture 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 may, where appropriate, consult with that Department 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 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, and
- 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, and
- 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 key 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 of Agriculture:

- 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
- assesses the probable extent of the harm that would result.

If the assessed level of quarantine risk exceeds Australia's ALOP, the Department of Agriculture 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 may be carried out by the Department of Agriculture's specialists, but 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 of Agriculture'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 2013a).
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 2013a).
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 2013a).
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 2013a).
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO 2013a).
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 Commonwealth Department of Agriculture.
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 2013a).
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 2013a).
Equivalence (of phytosanitary terms)	The situation where, for a specified pest, different phytosanitary measures achieve a contracting party's appropriate level of protection (FAO 2013a).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2013a).
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 2013a).
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 2013a).
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 2013a).
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 2013a).
Intended use	Declared purpose for which plants, plant products, or other regulated articles are imported, produced or used (FAO 2013a).
Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment (FAO 2013a).
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 IPPC (FAO 2013a).
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO 2013a).
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 <i>Phytophthora</i> , mycelium is non-septate, but plugs, often called false septa, can be seen in old mycelium (Erwin & Ribeiro 1996).
National Plant Protection Organization (NPPO)	Official service established by a government to discharge the functions specified by the IPPC (FAO 2013a).
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 2013a).
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 2013a).
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2013a).
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 2013a).
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 2013a).
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 2013a).
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 2013a).
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 2013a).
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 2013a).
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 2013a).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2013a).
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 2013a).
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 2013a).
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 2013a).
Phytosanitary certification	Use of phytosanitary procedures leading to the issue of a phytosanitary certificate (FAO 2013a).
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 2013a).
Phytosanitary procedure	Any official method for implementing phytosanitary measures including the performance of inspections, tests, surveillance or treatments in connection with regulated pests (FAO 2013a).
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 2013a).
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 2013a).
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 2013a).
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 2013a).
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 2013a).
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 2013a).
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 degrees Celsius 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 2013a).
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 2013a).
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 2013a).
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).

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