

Threat abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi*

March 2017

DRAFT FOR COMMENT

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1. Introduction

Thousands of Australian native plant species are susceptible to *Phytophthora* dieback, a destructive disease caused by the pathogen *Phytophthora cinnamomi* and other *Phytophthora* species. This disease is a major threat to Australia's biodiversity, placing important plant species at risk of death or even extinction. Its dramatic impact on plant communities can also result in major declines in some insect, bird and animal species due to the loss of shelter, nesting sites and food sources. *Phytophthora* dieback can cause permanent damage to ecosystems, and once an area is infested with the pathogen, eradication is usually impossible.

This national threat abatement plan (TAP) addresses the key threatening process, 'Dieback caused by the root-rot fungus'¹ *Phytophthora cinnamomi*, which is listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The TAP establishes a national framework to guide and coordinate Australia's response to *P. cinnamomi*. It sets out the actions necessary to abate impacts of the listed key threatening process and was developed to comply with the requirements under the EPBC Act for the development of threat abatement plans. It identifies the research, management and other actions needed in Australia's response to this pathogen and replaces the threat abatement plan published in 2014 (Department of the Environment, 2014).

The plan has been developed with the involvement and cooperation of a broad range of stakeholders, but the making or adoption of this plan does not necessarily indicate the commitment of individual stakeholders to undertaking any specific actions. Proposed actions may be subject to modification over the life of the plan due to developments in understanding of the organism and its impacts.

The Australian Government Department of the Environment and Energy is responsible for preparing this TAP. Its development has been informed by:

- a review and evaluation of the 2001 TAP undertaken by the Australian Government (CPSM, 2006)
- information provided by key stakeholders between 2014 and 2017
- the 2014 threat abatement plan.

This plan should be read in conjunction with the document 'Background: Threat abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi*' (the background document) (Department of the Environment and Energy, 2017). The background document provides information on the scope of the problem; the characteristics, biology and distribution of the pathogen; impacts on the environment and management practices (as at 2017).

The goal of this TAP is to identify and protect environmental assets (threatened species and ecological communities listed under the EPBC Act and other matters of national environmental significance) from the impacts of *P. cinnamomi*. It integrates: strategies to prevent *P. cinnamomi* spreading into areas that are free of disease; strategies to reduce the impacts in infested areas; recovery actions for the conservation of biodiversity assets currently being impacted; and research actions needed to find actions to mitigate the impact of *P. cinnamomi*.

The Department of the Environment and Energy recognises that a number of the state and territory governments that own land impacted by *P. cinnamomi* have developed management plans and operational guides to abate this threat within their own jurisdictions. This TAP aims to complement

¹ It is now understood that *P. cinnamomi* is not a fungus. This was the name of the key threatening process when it was registered under the EPBC Act.

state and territory approaches to managing *P. cinnamomi*.

Although this TAP applies to *P. cinnamomi*, the Department of the Environment and Energy acknowledges that diagnostic techniques have allowed other species of *Phytophthora* to be identified in Australia. Some of these species may be widespread and can lead to disease impacts similar to *P. cinnamomi* within native ecosystems. For further information on these species, a reference list is provided at Appendix B in the background document (Department of the Environment and Energy 2017). The control of pathways for the spread of *P. cinnamomi* and the development of improved control and remediation tools and techniques will also reduce the potential spread and impacts of other *Phytophthora* species.

1.1 Threat abatement plans and implementation

The EPBC Act prescribes the process, content and consultation to be followed when making a TAP to address a listed key threatening process. Under Section 270(A) of the EPBC Act, the Australian Government:

- develops TAPs where the Minister agrees that the making of a TAP is a feasible, efficient and effective way to abate a key threatening process.

Under Section 269 of the EPBC Act, the Australian Government:

- implements TAPs to the extent they apply in areas under Australian Government control and responsibility. Australian Government agencies must not take any actions that contravene a TAP
- seeks the cooperation of the affected jurisdictions in situations where a TAP applies outside Australian Government areas in states or territories, with a view to jointly implementing the TAP.

The success of this TAP will depend on a high level of cooperation between all key stakeholders, including:

- Australian Government departments and agencies
- state and territory conservation and natural resource management agencies
- local governments
- research institutes
- industry and entrepreneurs, including the forestry, garden and nursery, mining, and road construction industries
- the general community, including non-government environmental organisations and private conservation land management bodies, private landholders, Indigenous communities and natural resource management groups.

It will be important that land managers assess the threats and impacts of *P. cinnamomi* and allocate adequate resources towards effective on-ground prevention of spread and management of impacts, improving the effectiveness of prevention and management programs, and measuring and assessing outcomes.

In order to successfully implement this TAP, the Department of the Environment and Energy will:

- coordinate its implementation as it applies to Commonwealth land and act in accordance with the provisions of the TAP, as required under the EPBC Act
- seek stronger coordination of national action on *P. cinnamomi*
- draw on expertise from state and territory agencies and non-government organisations

- encourage involvement of key stakeholders and experts in *P. cinnamomi* related research and management.

The Australian Government will monitor the uptake and effectiveness of management actions by all parties as part of a review of the TAP under Section 279 of the EPBC Act. Where the Australian Government and state and territory governments have mutual obligations, negotiation of appropriate actions and funding of management actions will be undertaken.

1.2 The pathogen

Phytophthora is a major genus within the diploid, alga-like phylum Oomycota (Cooke et al., 2000). This group is currently referred to as water moulds and, although it was previously referred to as fungi, in taxonomic terms it is more closely related to algae. As *P. cinnamomi* has the ability to cause plant disease and plant death, this document refers to this species of water mould as a pathogen. At least 32 species of *Phytophthora* occur in various parts of Australia. Other species of *Phytophthora*, including *P. cryptogea*, *P. megasperma*, *P. multivora* and *P. arenaria* are also known to cause significant damage in the wild, particularly in Western Australia. However, much more extensive damage has resulted from the presence of *P. cinnamomi*.

P. cinnamomi was probably introduced to Australia with European settlement and since the mid-1960s, has been recognised as a serious threat to many native plants and ecosystems, important crops and horticultural plants.

P. cinnamomi is known to occur in all Australian states and territories; with the exception of the Northern Territory, where it is generally accepted that the environmental conditions are not conducive to the pathogen's establishment and persistence in susceptible native plant communities. The area of Australian native vegetation affected by *Phytophthora* species exceeds a million hectares, and continues to increase. It has been reported that more than 1 million hectares are affected in Western Australia alone. Recorded isolations, records of impact and a broad climatic envelope of *Phytophthora* species susceptibility in Australia are depicted in a map in the background document (Department of the Environment and Energy, 2017).

The pathogen is now well established in many of the country's higher rainfall areas (areas with a mean annual rainfall greater than 600 millimetres). Although higher rainfall areas are more favourable, the distribution of *P. cinnamomi* has been reported in areas with average yearly rainfall as low as 400 millimetres (Brasier and Scott, 1994). The most favourable conditions for spore production are free water and warm temperatures. Soils that are neutral pH to acidic are most favourable for the sporulation and survival of *P. cinnamomi* (Zentmyer, 1980).

The development of the disease, *Phytophthora* dieback, requires a number of factors that must operate in concert. These are: the presence of the pathogen; the presence of susceptible host plant species; and environmental conditions that favour infection and subsequent reproduction and spread of the disease (Garkaklis et al., 2004).

Plants become visibly diseased when infection results in the impairment of the plant's physiological and biochemical functions. Roots are a primary site of infection and therefore uptake of water is one of the first functions affected. This is why symptoms of *P. cinnamomi* infection have similarities, at least initially, with those of water-stress. For susceptible species, apparently healthy plants (in groups or individually) can suddenly die. Less susceptible species can show crown decline symptoms, including leaf yellowing and death of primary leaf-bearing branches. Epicormic branches with smaller leaves can develop, and over time epicormic branches will decline, with an overall thinning of the crown. Trees with such symptoms can take a number of years to decline and die. The removal of bark at the base of trees just above or below the soil line can reveal areas of necrosis. These necrotic areas effectively girdle the trees and cause death.

P. cinnamomi can be spread in water, soil or plant material that contains the pathogen and dispersal is favoured by moist or wet conditions. It can be carried in both overland and subsurface water flow and by water moving infested soil or organic material. Native and feral animals have been implicated in spreading *P. cinnamomi*, particularly where there are digging behaviours. Humans, however, have the capacity to disturb and transport more soil than any other vector. Most of the large centres of infestation that exist today in southern temperate Australia occurred as a result of human activity, often as a direct result of the introduction of infested soil or road-building materials to vulnerable un-infested areas (O’Gara et al., 2005b). A list of human assisted spread mechanisms is in section 1.4 of this TAP.

Zoospores from the pathogen can swim short distances in free water. *P. cinnamomi* grows through roots and can spread to the roots of adjacent plants where root-to-root contact occurs. Root-to-root movement of the pathogen is thought to be one of the major ways in which the pathogen moves upslope (O’Gara et al., 2005b). Under less favourable conditions, *P. cinnamomi* produces asexual reproductive structures known as chlamydospores, which can survive for several years until conditions improve. Recently, in Western Australia, *P. cinnamomi* has been shown to survive asymptotically in a range of native annual and herbaceous perennial species (Crone et al., 2012; Crone et al., 2013a) and in some species to survive as a biotroph. In addition it can, in some hosts, produce numerous selfed oospores which would allow it to survive adverse conditions when necessary (Crone et al., 2013b). These research findings may have important implications for the future management of *P. cinnamomi*.

It is important to note the intractable nature of disease caused by *P. cinnamomi*, but also that actions which ameliorate its effects—particularly on endangered species and communities—are vital to the conservation of Australia’s biodiversity.

1.3 Impacts of *Phytophthora cinnamomi*

1.3.1 Ecological impacts on plants

Healthy natural environments provide a range of direct and indirect benefits, which are threatened by disease caused by *P. cinnamomi*. This disease is often difficult to detect and can cause significant and permanent damage to ecosystems before detection.

The consequences of infection of susceptible ecological communities include:

- a dramatic modification of the structure and composition of the native plant communities
- a significant reduction in primary productivity and functionality
- habitat loss and degradation for dependent flora and fauna; to date these have been irreversible.

Hardham (2005) suggests that *P. cinnamomi* is likely to infect over 2500 Australian native species. The pathogen is a threat, or possible threat to 144 native plant species listed as threatened under the EPBC Act (see the list at Appendix A). It may threaten several of these plant species with extinction. In the South-West Botanical Province Shearer et al. (2004) have shown that approximately 41 per cent of 5710 vascular plant species are susceptible to the pathogen.

Susceptibility of plant species to disease caused by *P. cinnamomi* is complex, with considerable variation occurring within plant taxonomic units, making occurrence within a plant family or genus a poor predictor of species susceptibility (Shearer, 2004).

The Centre for *Phytophthora* Science and Management (CPSM) at Murdoch University has compiled lists of Western Australian native plant species that are resistant to disease caused by

P. cinnamomi (Groves et al., 2009a, 2009b). This information is available on the Dieback Working Group website (<http://www.dwg.org.au/>). Lists of field-resistant upland tropical rainforest species from Queensland are presented in Worboys and Gadek (2004). The lists have been compiled from field observations of resistance and the results of controlled experiments. However, the classification of a plant as resistant to *P. cinnamomi* often depends on other environmental factors (including climate) which can influence susceptibility to the pathogen. A species' resistance can also vary depending on the pathogen's genotype (Howard, 2008). A plant species' susceptibility occurs on a continuum between resistant and susceptible with genetic components within species, between species and within genera displaying variable susceptibility. As a result, a species should be considered as susceptible when greater than 50 per cent of the genetic population of the plant is killed when confronted by the pathogen.

Investigations over several years have discovered the mechanisms by which a limited number of plants are able to survive infection, including the activation of defence-related genes and signalling pathways, the reinforcement of cell walls and accumulation of toxic metabolites (Professor David Cahill, pers. comm., 2011). Genetically-based, intra-specific variation in resistance has been demonstrated in the Western Australia native hardwood, *Eucalyptus marginata* (jarrah) (Stukely and Crane, 1994), and in the exotic plantation species *Pinus radiata* (Butcher et al., 1984).

As well as affecting or killing individual plants in an area, *P. cinnamomi* will infect new plants as they grow from *in situ* seed banks. Over the longer term, this will exhaust the seed bank as many ecosystems affected by *P. cinnamomi* have limited seed dispersal capacity. In these situations, a localised extinction of the plant species will occur (Prof Kingsley Dixon pers. comm., 2017).

While *P. cinnamomi* directly threatens a range of individual plant species, it also threatens ecological communities and landscapes. Large areas of Western Australia, for example, where the pathogen is likely to have been present for over one hundred years, represent post dieback plant assemblages (Dr Joanna Young pers. comm., March 2012).

Indirect impacts on flora have also been demonstrated, for example, in South Australia, EPBC Act listed orchid species (for example *Caladenia argocalla*, *C. behrii*, *C. rigida*) are afforded some measure of protection from herbivores where they are found growing in close proximity to the fronds of *Xanthorrhoea semiplana* (grass trees). When grass trees become infected with *P. cinnamomi* and die, the orchids become exposed and are vulnerable to herbivory (Petit and Dickson, 2005).

Multiple processes may interact with *P. cinnamomi* to increase extinction risk (Barrett et al., 2008). For example, *P. cinnamomi* activity might be greater in some circumstances following a fire because there are fewer plants to use the available water and sites are more prone to water logging (Cahill et al., 2008).

1.3.2 Ecological impacts on wildlife

Although there has been a substantial amount of research on the effects of *P. cinnamomi* on vegetation in some states, there has been comparatively little work that has investigated the indirect effects of the disease on faunal populations and communities where food sources or habitat is threatened by the disease (Cahill et al., 2008). Phytophthora dieback could lead to permanent losses for nectarivorous fauna dependent on susceptible systems.

Garkaklis et al. (2004) reviewed the literature on the responses of forest animal communities to the presence of *P. cinnamomi*. This review indicated that, for a range of forest fauna, serious impacts were either occurring or were plausible but not yet demonstrated. Many of these impacts will arise because of changes in species richness and composition, and alterations to the structural composition of habitats. Species likely to be affected include some listed as endangered under the

EPBC Act.

An example recently demonstrated by Dundas et al. (2013), is *Tarsipes rostratus* (honey possum) that visits many taxa that are susceptible to *Phytophthora dieback*. The inevitable spread of *Phytophthora* and its associated changes to vegetation composition is postulated to result in the localised loss of resources for honey possums and is a concern for ongoing conservation management.

1.3.3 Impacts on matters of national environmental significance

EPBC Act listed threatened species or listed threatened ecological communities are matters of national environmental significance protected under the Act. Appendices A and B of this TAP provide details of listed threatened species and ecological communities that are being impacted or that have the potential to be impacted by *P. cinnamomi*.

Under the EPBC Act, *P. cinnamomi* is treated as a key threatening process as a result of these impacts or potential impacts, including the potential for the pathogen to cause native species or ecological communities not yet listed to become eligible for listing.

Other matters of national environmental significance impacted, or potentially impacted by the presence of *P. cinnamomi* (through destruction of vegetation and subsequent damage to an area's significance) are:

- world heritage areas
- national heritage places
- Commonwealth heritage on Commonwealth lands
- Ramsar wetlands (i.e. wetlands listed under the Convention on Wetlands of International Importance).

P. cinnamomi is known to have impacted on the following world heritage areas:

- Wet Tropics World Heritage Area of North Queensland. More than 200 patches infected with *P. cinnamomi* have been found, mostly in wet notophyll vine forests above 700 metres on acid volcanic soils. These forests comprise 14 per cent of the World Heritage Area.
- Gondwana Rainforests of Australia World Heritage Area of northern New South Wales and southern Queensland.
- Greater Blue Mountains World Heritage Area. Detected in various sites including the Wollemi Pine (listed as endangered) site.
- Tasmanian Wilderness World Heritage Area. *P. cinnamomi* is prevalent across Tasmania and also occurs within the World Heritage Area where it is having a widespread and severe impact within buttongrass moorland vegetation.
- Lord Howe Island World Heritage Area. *P. cinnamomi* has been recorded from one lease in the southern part of the island's settlement area and could potentially spread to the Lord Howe Island Permanent Park Preserve on footwear or vehicles (DECCW, 2010).

National heritage places for which *P. cinnamomi* is a known threat include:

- The Stirling Range National Park, Porongurup National Park and Fitzgerald River National Park in south-west Western Australia. *P. cinnamomi* is a significant threat to plant communities of outstanding richness and endemism.
- The Grampians National Park (Gariwerd) in Victoria, where *P. cinnamomi* has been recorded at many sites and longer term studies have shown wide-scale changes in their floristic

composition.

- The Tasmanian Wilderness and Western Tasmania Cultural Landscape (the Tarkine).
- The Gondwana Rainforests of Australia.
- The Lord Howe Island Group in the Tasman Sea.

Ramsar listed sites known to be affected by *P. cinnamomi* include Lavinia Wetland on the north-east coast of King Island, Tasmania (Parks and Wildlife Service, 2000); the Lake Warden System at Esperance, on the south coast of Western Australia (DEC, 2009); and Forrestdale Lake in Perth, Western Australia (Conservation Commission of Western Australia, 2005).

Although not listed as a matter of national environmental significance under the EPBC Act, an area being significantly impacted by Phytophthora dieback that is of national importance is the Fitzroy River National Park in Western Australia. This area is a reserve site recognised under UNESCO's² Man and the Biosphere Program. The EPBC Act includes provisions for cooperative arrangements between the Commonwealth, states and territories in the development of biosphere reserves.

1.3.4 Interaction of *P. cinnamomi* with other threats

Growing understanding of the interactions between *P. cinnamomi* and other threats to biodiversity will increasingly inform future management decisions, for example, when evaluating the costs and benefits of minimising fire frequency.

In a study of heathlands in south-western Australia Moore et al. (2014) predict that the likely increase of open sites and wetter conditions immediately after a fire would create ideal conditions for the spread of *P. cinnamomi* to surviving species. This interaction has important implications for the future of plant communities threatened by infestation from the pathogen.

Due to the urgency of fire management situations, there may be a breakdown of hygiene protocols, If contaminated water, vehicles and equipment is used during fire suppression or prescribed burns, *P. cinnamomi* can be spread or introduced to clean areas.

An effect of burning is to increase the levels of nutrients in soils that could increase sporulation rates (Moore 2005, Prof K Dixon pers. comm., 2017 from information provided by Professor GA Zentmyer). This can create management challenges for reducing the spread of *P. cinnamomi* to new areas.

Forestry operations also have the potential to spread the pathogen via machinery, vehicles and equipment. Stringent hygiene protocols during these operations can lower the risk of spread. In addition, thinning of the forest can result in elevated water levels and temperatures ideal for the rapid growth of *P. cinnamomi* (Bunny et al. 1995).

Section 1.5 below discusses the potential effects of climate change in relation to *P. cinnamomi*.

1.4 Managing the threat

Containment methods are available to prevent the spread of the pathogen and in rare cases, eradication of very small infestations is possible (Dunstan et al., 2011). However, further work is

² United Nations Educational, Scientific and Cultural Organisation

required to:

- minimise the spread of *P. cinnamomi* to uninfested sites
- mitigate the impact of *P. cinnamomi* at infested sites.

A priority is to minimise the spread and mitigate the impact of *P. cinnamomi* in areas containing biodiversity assets of high conservation value including:

- threatened species or ecological communities susceptible to *P. cinnamomi*
- habitat susceptible to *P. cinnamomi* and critical to the survival of threatened fauna.

P. cinnamomi may cause native species or ecological communities not yet listed under the EPBC Act to become eligible for listing (in any category, other than conservation dependent). This means that it is also important to address the impacts and spread of *P. cinnamomi* in areas that:

- support high plant species endemism
- support high species diversity for a type of vegetation
- support significant remnant vegetation as per state or territory criteria
- are large, ecologically intact and mostly undisturbed
- support susceptible species listed as threatened at the state or territory level.

1.4.1 Minimising the spread

Humans can spread *P. cinnamomi* further and faster than any other infestation vector. Adhering to stringent hygiene protocols before entering or leaving a site can help minimise the spread of the pathogen. High risk activities for spread include:

a) Emergency and land management activities

- Fire management, including:
 - emergency firebreak construction
 - fire fighting using *P. cinnamomi* contaminated water and/or equipment
 - movement of contaminated equipment into uncontaminated areas due to non-compliance with, or careless implementation of, hygiene procedures
- Flood mitigation works, involving:
 - movement of contaminated gravel, sand, soil etc.
 - movement of contaminated equipment
- Use of contaminated nursery material and soil disturbance associated with revegetation and restoration activities
- Weed and feral animal control activities

b) Recreational activities

- Camping
- Bushwalking, geocaching, rogaining, orienteering
- Fishing and marroning/yabbing
- Mountain bike riding
- Horse riding
- Recreational vehicles (for example motor bikes, quad bikes, four wheel drives)

- Trail biking
- Hunting

c) Commercial and other activities

- Environmental/ecological surveys or research activities (for example flora, fauna, vegetation mapping, geological surveying)
- Tourism, particularly ecotourism
- Timber and wild flora harvesting
- Defence force training
- Mining exploration and mining
- Seed collecting
- Soil and gravel extraction
- Firewood cutting
- Apiculture (beekeeping)
- Road construction (widening, realignment, maintenance)
- Maintenance of recreational tracks and walking trails
- Construction of straight line infrastructure (for example powerlines and telecommunication structures)
- Propagation and distribution of infected plants, soil and mulch for commercial purposes (for example nursery and gardening industries)
- Irrigated cropping

The limited management options available focus on modifying human activities by education, restricting access to certain sites, and, when access is necessary, deploying and enforcing hygiene procedures to minimise the spread of *P. cinnamomi* in the landscape.

State government agencies have developed documents detailing hygiene methodologies for work and recreation in and around *P. cinnamomi* management areas. In addition, the Dieback Working Group (Western Australia) has produced *Managing Phytophthora dieback in bushland—a guide for landholders and community conservation groups* (2008) and NRM South (Tasmania) has published *Keeping it Clean* (Allan and Gartenstein, 2010). These methodologies are applicable nationally.

Leave No Trace Australia (www.LNT.org.au) is a national and international minimal impact education program for the recreation, tourism, outdoor education, and land and sea management sectors that focuses on biosecurity as one of its strategic awareness outcomes, including Phytophthora dieback awareness. Working with partners at a state, national, and international level across government, non-government and industry sectors, the Leave No Trace program is delivered as a community and formal education program that seeks to raise awareness of natural and cultural heritage values and the appropriate practices to mitigate the threats to those values.

States have prepared useful approaches for training and awareness-raising directed at reducing the spread of the pathogen. For example:

- The Western Australian Department of Parks and Wildlife (WA DPAW) is introducing a 'green card' program and an environmental code of conduct for contractors. Contractors working on-site are given one half day training on environmental threats, including *P. cinnamomi* and appropriate responses to these threats. This training could be redeveloped for national use to

train staff and contractors working in high priority conservation areas, including land management agency staff.

- The Victorian Department of Environment and Primary Industries has a one day workshop, the WeedStop Vehicle Hygiene Program, that can be customised to deal with *P. cinnamomi* from which participants qualify with a Certificate of Attainment in the nationally accredited unit.
- Regional-scale hygiene methodologies have been developed for the Wet Tropics of North Queensland, where dieback management procedures apply to operational works within the World Heritage Area (Worboys and Gadek, 2004).

The use of the biodegradable, systemic fungicide phosphite to assist existing management strategies has been recommended for protection of susceptible vegetation communities (Aberton et al., 1999; Aberton, 2003). The strategic application of phosphite has been shown to reduce the rate of autonomous spread of the pathogen. Phosphite is examined in more detail below.

Major containment and spot eradication projects for *P. cinnamomi* have been undertaken by WA DPAW in both the Fitzgerald River and Cape Arid National Parks in Western Australia.

1.4.2 Mitigating the impact

The tools available for mitigating the impact of *P. cinnamomi* are limited. The strategic use of phosphonic acids (for example phosphite) and selected fumigants has management potential for impact reduction, containment and spot eradication of the pathogen. An integrated approach with use of these chemicals, strict access and hygiene controls can successfully mitigate the impact and minimise the spread of the pathogen.

a) Phosphite

The term 'phosphite' refers to salts of phosphonic acid (H_3PO_3). Phosphite treatment induces a strong and rapid defence response in the treated plant. These defence responses stop pathogen spread in a large number of hosts. Phosphite needs to enter a plant's water transport system in order to be effective. This is achieved by stem injection of phosphite into trees, or spraying phosphite onto the leaves of accessible plants. Injection provides the trees with protection for at least four years (Shearer & Fairman, 2007), while spraying the leaves provides protection for one to two years. Efficacy may vary between and within species being treated.

Phosphite has been used to mitigate the impacts of *P. cinnamomi* on some vulnerable species at infested sites in Western Australia and Victoria. However, phosphite has been found to act as a fertiliser in some circumstances and requires further testing on a greater range of vulnerable species, particularly in other states and territories. Long term phosphite use may have a fertiliser effect in native plant communities occurring on soils with low phosphorous levels resulting in deleterious changes to the plant community (Lambers et al., 2013). The possible deleterious effects of treatment should be included in all monitoring where phosphite is being applied within native plant communities. Further research is required into the adverse impacts of phosphorous and effective alternatives to phosphite use.

The Dieback Working Group has produced instruction leaflets on spraying and stem injection of phosphite. These are available on the Dieback Working Group website (<http://www.dwg.org.au/>).

b) Other impact mitigation methods

A method for eradicating very small infestations of *P. cinnamomi* has been developed and could be applied strategically in suitable areas where priority biodiversity assets occur. The process involves a sequence of treatments: vegetation (host) destruction, fungicide and fumigant

treatments, and containment barriers to protect threatened vegetation (Dunstan et al., 2010; Dunne et al., 2011). This method greatly increases the potential for spot eradicating *P. cinnamomi* in patches with sandy soils, dominated by root-to-root transmission (refer to the case study in the background document for more detail). Eradication efforts in clay or rocky soils dominated by water associated spread have proven more problematic.

A more recent study by Crone et al. (2012) has shown that, from a management perspective, the above technique may not be successful if annual and herbaceous perennial plant species are allowed to remain. These plants, even without symptoms, may act as hosts of *P. cinnamomi*. An experimental investigation of the potential efficacy of host destruction is necessary before adopting this method. It should be emphasised that the clearing of vegetation to remove the hosts of *P. cinnamomi* would only be suitable for very small areas.

WA DPAW has developed an assessment of site variables that influence whether eradication or containment of *P. cinnamomi* is likely (see Appendix E in the background document (Department of the Environment and Energy, 2017)).

Ex situ conservation of germplasm in seed banks is a well-established technique used to conserve wild plant genetic diversity and may support the management and conservation of plant species and communities. Guidelines have been prepared for plant germplasm conservation in Australia (ANPC, 2009). By contributing to projects to collect and preserve viable seeds in conservation seed banks in Australia (ASBP, 2017), the Department of the Environment and Energy has assisted to build a comprehensive and genetically diverse *ex situ* collection of native plant taxa that are listed as threatened under the EPBC Act that are at risk from *P. cinnamomi*.

In situ conservation, or translocation is the deliberate transfer of plants or regenerative plant material from one place to another for the purpose of enhancing genetic diversity and habitat for conservation. In employing this method, disease must be absent from any material moved. Guidelines for the translocation of threatened plants in Australia (Vallee et al., 2004) take into account the benefits, risks, planning and implementation associated with the strategy.

Breeding for resistance is another potential impact mitigation method although, to date, research has not achieved resistance so it may be limited in its application. There is considerable variation in resistance within a species or between species within the same genus or subgenus. Enhancing the process of natural selection for resistance may be a longer term management option for some taxa. Future research may also allow for the transfer of resistance genes into those taxa that at present appear to have no resistance. However, an improved understanding of the genetic basis of resistance and the genetic diversity of *P. cinnamomi* will be essential for this work. Initially, the availability of samples of *P. cinnamomi* cultures, isolated and collected from a wide range of natural ecosystems, would facilitate any research.

More information on the use of phosphite, containment activities and other management measures undertaken in Australia can be found in the background document (Department of the Environment and Energy, 2017).

1.5 Climate change

It is difficult to predict how changing climate parameters will impact *Phytophthora* dieback. It could affect habitat suitability of the disease as well as the ability of particular plant species to resist it. As different species become exposed, plant assemblages in ecosystems are likely to change. It is also likely that the effects of climate change will significantly alter the distribution and severity of *P. cinnamomi* infestations. With predicted average temperature increases of between 1°C and 5°C in Australia by the year 2070 (CSIRO and Bureau of Meteorology 2007-2012), it is probable that

Phytophthora dieback will extend into areas (for example, arid and higher altitude regions) that were previously unsuitable for the establishment of the pathogen. In contrast, some areas predicted to have reductions in rainfall could become less conducive to pathogen activity or establishment. The effect of vegetation change on soil temperatures is harder to predict than air temperature changes. This may be a major determinant of the changed distribution of *P. cinnamomi* in some situations. Recent modelling (CPSM, 2013) will be useful to managers and policy makers involved in ensuring the spread and impact of *P. cinnamomi* is contained in the future. For a more detailed discussion of the potential interactions between *P. cinnamomi* and climate change, please refer to the background document (Department of the Environment and Energy, 2017).

2. Objectives and Actions

The goal of this TAP is to minimise the impacts of *P. cinnamomi* on matters of national environmental significance (NES) under the EPBC Act and priority biodiversity assets (that will include matters of NES) identified by the actions of this TAP. To achieve this goal, the TAP has four objectives.

1. Identify and prioritise for protection:

- biodiversity assets
- areas where there is potential for *P. cinnamomi* to cause native species or ecological communities not yet listed to become eligible for listing under the EPBC Act (in any category, other than conservation dependent).

2. Reduce the spread of *P. cinnamomi* to, and reduce its impacts on:

- identified priority biodiversity assets
- areas where there is potential for *P. cinnamomi* to cause native species or ecological communities not yet listed to become eligible for listing under the EPBC Act (in any category, other than conservation dependent).

3. Communicate information about *P. cinnamomi*, its impacts on biodiversity and actions under this TAP.

4. Encourage research into further mitigation options for the impacts of *Phytophthora cinnamomi*.

Each objective is accompanied by a set of actions which, when implemented, will help achieve the goal of the TAP. Performance indicators have been established for each action. The priorities stated for actions are relative over the life of the TAP. Timeframes listed for the actions are:

- short term, 1–3 years
- medium term, 3–5 years
- long term, more than 5 years
- ongoing.

Research actions have been identified that will support the TAP to achieve its goal. These are listed at the end of this section.

Objective 1: Identify and prioritise for protection biodiversity assets that are, or may be, impacted by *Phytophthora cinnamomi*

There is a need to determine the risks *P. cinnamomi* poses to biodiversity assets across Australia and develop a list of national priority biodiversity assets for protection. Attention is drawn to the discussion in the background document on state-based approaches to the assessment of risks from *P. cinnamomi*.

Appendix A shows EPBC Act listed plant species which may be at risk from *P. cinnamomi*. Appendix B shows EPBC Act listed threatened ecological communities that may be at risk from *P. cinnamomi*. Although understanding of plant species' susceptibility and impacts on dependent

wildlife is still developing, these lists provide a starting point for prioritisation.

Threatened species and communities are also listed under state and territory legislation. Australian Government and state/territory lists do not necessarily align, creating the potential for inconsistency in priorities.

Risk assessment methodologies should be the basis for governments in setting management priorities and allocating resources. The risk assessment process extends beyond those susceptible plant species and ecological communities that are currently listed as threatened under the EPBC Act. It also covers those that are at risk of becoming listed due to factors such as proximity to infested areas, and extends to habitat dependent wildlife and plant species that may be impacted by *Phytophthora dieback*.

Action	Responsible party	Priority	Timeframe	Performance indicators
Action 1.1 Identify impacts and prioritise flora, fauna and communities at risk to inform <i>P. cinnamomi</i> management.	Australian Government and state and territory governments	High priority	Medium term	Flora and fauna species at risk are identified and prioritised. Ecological communities at risk are identified and prioritised. The threat of <i>Phytophthora dieback</i> is evaluated during the review or development of Commonwealth recovery plans and conservation advices.
Action 1.2 Identify risk areas spatially to generate lists of biodiversity assets at risk from <i>Phytophthora dieback</i> —develop or utilise existing prioritisation frameworks.	Australian Government and state and territory governments	High priority	Medium term	Risk areas identified spatially within three years of the making of this TAP through preparation of: <ul style="list-style-type: none"> maps of potential national distribution of pathogen maps of priority biodiversity assets.
Action 1.3 Identify priority biodiversity assets and areas for protection at a local scale—develop or utilise existing prioritisation frameworks.	State, territory and local governments	High priority	Medium term	Revise and produce local scale maps of priority biodiversity assets and protection areas.
Action 1.4 Improve and maintain current monitoring programs.	Australian Government and state and territory governments	Very high priority	Medium term	New infestations in areas of priority biodiversity assets and protection areas are detected and monitored annually.

Objective 2: Protect priority biodiversity assets through reducing the spread and mitigating the impacts of *P. cinnamomi*

To direct the limited resources available for implementing threat abatement activities to the greatest benefit, this TAP directs action to safeguard priority biodiversity assets from the spread of *P. cinnamomi* both to them and within them. It also directs action to mitigate the impacts of *P. cinnamomi* on priority biodiversity assets.

Action	Responsible party	Priority	Timeframe	Performance indicators
Action 2.1 Assess the appropriateness of registration of phosphite for management of <i>P. cinnamomi</i> in natural ecosystem contexts. If appropriate and feasible, initiate registration by the Australian Pesticides and Veterinary Management Authority.	State and territory governments	High priority	Short term	Phosphite is assessed for its appropriateness to be registered as a control method for Phytophthora dieback in natural systems. Required research is identified and conducted for registration (if appropriate). Process for registration of phosphite for national use in natural ecosystem contexts has commenced (if appropriate).
Action 2.2 Implement control actions to protect priority biodiversity assets (as identified under Objective 1) from the impacts of <i>P. cinnamomi</i> .	Australian Government and state, territory and local governments	High priority	Ongoing	Quarantine and hygiene measures for priority biodiversity assets are implemented during the life of this TAP. Where suitable eradication, containment or control methods are applicable, these are implemented throughout the life of this TAP (e.g. eradicate small infestations to protect high value healthy catchments). <i>Ex situ</i> conservation of species at risk is undertaken at appropriate facilities that manage the risk of <i>P. cinnamomi</i>

Action	Responsible party	Priority	Timeframe	Performance indicators
<p>Action 2.3</p> <p>Develop and implement practices to minimise the inadvertent spread of <i>P. cinnamomi</i> to priority biodiversity assets.</p>	<p>Australian Government, state, territory and local governments and relevant industries conducting high-risk activities (e.g. forestry, garden/nursery, road construction, recreation, mining and tourism)</p>	<p>High priority</p>	<p>Short term and ongoing</p>	<p>introduction.</p> <p>Risk reduction plans (prevention, impact reduction, containment, stakeholder engagement, communication materials including signage, monitoring) for priority protection areas and biodiversity assets are prepared.</p> <p>Implement a voluntary certification scheme Australia-wide for high risk materials such as nursery materials, soils, quarry products and road and track building material.</p> <p>Pathogen-tested raw materials, compliant with a best practice certification scheme, are used in high-risk infestation pathways such as soil and nursery materials.</p>
<p>Action 2.4</p> <p>Integrate management of <i>P. cinnamomi</i> with other natural resource management systems, especially fire management, including emergency suppression protocols, and prescribed fires.</p>	<p>Australian Government and state and territory governments</p>	<p>Medium priority</p>	<p>Medium term</p>	<p>State and territory governments have adopted integrated hygiene procedures for works in native vegetation to manage pests, weeds and disease risks.</p> <p><i>P. cinnamomi</i> management is integrated with other compatible land management programs such as revegetation, fire, weed and pest management and road maintenance programs.</p>

Action	Responsible party	Priority	Timeframe	Performance indicators
Action 2.5 Promote use of guidelines to minimise risks from <i>P. cinnamomi</i> arising from Australian Government environment funding programs.	Australian Government	High Priority	Ongoing	Guidelines to minimise risks from <i>P. cinnamomi</i> are communicated to funding recipients and reviewed and updated as necessary.

Objective 3: Communication and training

There are limited options for managing *Phytophthora* infestations, so preventing its spread is vital. As the cumulative impacts of *Phytophthora* dieback cause further permanent damage to Australian landscapes, it is increasingly important to reinvigorate concern and publicise the importance of spread minimisation. National coordination and sharing of state/regional communications approaches can help lift awareness of this threat to a higher level. This should include clear communication to land managers and land users of:

- the approach adopted in this TAP
- the scale of the threat to biodiversity posed by *P. cinnamomi* and other *Phytophthora* species
- the priority biodiversity assets that need protection
- the tools and practices that will minimise the inadvertent spread of *P. cinnamomi*
- the necessity for land managers in conservation, forestry, horticulture, agriculture, and water resources to be trained to an appropriate level in the science and management of *P. cinnamomi*
- the need for integration of *P. cinnamomi* management, education and training with other natural resource management activities.

A number of networks of conservation groups and researchers with an interest in *P. cinnamomi* already exist. Networks such as the Dieback Working Group, Project Dieback in Western Australia, Leave No Trace Australia and the Australian Network for Plant Conservation can assist in communicating developments in the management of *P. cinnamomi*, host susceptibility and other issues. The appointment of a Dieback Coordinator to relevant local government areas may also assist in providing guidance and coordination for dieback matters at the local and regional scale.

Action	Responsible party	Priority	Timeframe	Performance indicators
Action 3.1 Develop and implement a national communications strategy to raise awareness of the threat of <i>Phytophthora</i>	Australian Government and state and territory governments	High priority	Medium term and ongoing	Responsible parties work together towards a coordinated communications strategy to raise awareness of the threat nationally. Effective communication actions are progressed during the life of

Action	Responsible party	Priority	Timeframe	Performance indicators
dieback and the importance of preventing spread. Determine stakeholders, key messages and the most efficient means of communicating with stakeholders on issues relating to <i>P. cinnamomi</i> impacts on priority biodiversity assets.				the TAP. Research and other findings are assessed, documented and communicated to stakeholders.
Action 3.2 Build awareness and develop and provide training for industry, land and tourism managers, peak organisations (recreation and outdoor education) and recreation clubs and societies.	Australian Government, state and territory governments and industry	Medium priority	Short term and ongoing	Training material on the methodologies involved in detection, diagnosis and management of <i>P. cinnamomi</i> are developed or updated, as required and made available. This material is then integrated into training associated with land planning and management, and biodiversity conservation. Industry-specific codes of practice for the management of <i>P. cinnamomi</i> are readily available and implemented by the proponents of activities in high-risk areas and high-value sites, including: supply of nursery materials; transporting of soil; quarrying; road and track building; land restoration; natural area recreation such as bushwalking, motorised recreation, fishing, hunting and mountain-biking; agriculture and horticulture; and the disposal of <i>P. cinnamomi</i> infested material.
Action 3.3 Ensure that guidelines, including codes of practice and standard operating procedures, for managing <i>P. cinnamomi</i> are available to key stakeholders and are	Australian Government and state, territory and local governments	High priority	Ongoing	Up to date guidelines, including codes of practice and standard operating procedures, are available electronically and in hard copy to key stakeholders and reviewed in terms of their effectiveness on an ongoing basis.

Action	Responsible party	Priority	Timeframe	Performance indicators
implemented, reviewed and updated.				
Action 3.4 Develop or adopt a national system of signage and alerts to guide park visitors and land managers in affected priority areas.	Australian Government and state, territory and local governments	Medium priority	Medium term	A national system of signage and alerts using standardised placement requirements and terminology is available for use in managing <i>P. cinnamomi</i> in priority areas.
Action 3.5 Acquire and maintain up to date information on <i>P. cinnamomi</i> and the progress of the TAP.	Australian Government	Medium priority	Ongoing	<p>The Department of the Environment and Energy hosts a regular forum with key stakeholders to assist in implementation of the plan and to review achievements of the plan.</p> <p>The Department of the Environment and Energy website holds and maintains up to date information reflecting the achievements against TAP actions.</p> <p>The Department of the Environment and Energy reviews research actions, disseminates new information and promotes the uptake of findings.</p>

Objective 4: Encourage research into further mitigation options for the impacts of *Phytophthora cinnamomi*.

Research will contribute to informing the implementation of the objectives of this plan through improving our understanding of the pathogen and developing control and restoration techniques.

There is a lack of an effective, long-term control for *P. cinnamomi* that does not have other undesirable effects (such as phosphite increasing the fertility of the soil). A major research initiative is needed to address this problem and prevent further irreversible assemblage changes to ecological communities from the loss of vulnerable species. Major research projects are expensive to fund so a co-operative approach including government, philanthropic and corporate funding would be required.

In addition to the over-riding requirement to develop a control, there is also research needed to

understand the *Phytophthora* genus better, improve how we currently use phosphite to control *P. cinnamomi*, look into how we can assist native plants to have better resistance to the pathogen through selective breeding or gene manipulation and undertake long-term preservation of currently vulnerable species in the hope that restoration of those species to ecological communities may be possible in the future.

Action	Responsible party	Priority	Timeframe	Performance indicators
Action 4.1 Undertake further or new research into: <ul style="list-style-type: none"> developing new and effective treatments for the disease that minimise collateral impacts; eradication methods for a variety of soil types; techniques to develop resistance in vulnerable species 	Australian Government, state and territory governments and research organisations	High priority	Ongoing	Collaborative applied research projects are undertaken to test and improve eradication and species resistance.
Action 4.2 Encourage new partnerships (e.g. through the Australian Research Council or forestry, mining and nursery industries, philanthropists) to support the funding of research relating to the management of <i>P. cinnamomi</i> (and other <i>Phytophthora</i> species).	Australian Government, state and territory governments, research organisations, industry, philanthropists, and community	High priority	Ongoing	Approaches are made to seek corporate funding for research into the development of an alternative treatment to phosphite. Partnerships are initiated within 12 months of this TAP being made.
Action 4.3 Increase understanding of factors affecting pathogen distribution and expression (including climate change).	Australian Government, state and territory governments, research organisations and industry	Medium priority	Medium term	Material on factors affecting pathogen distribution and expression is published. Further research is conducted into the mechanisms of spread and survival of <i>P. cinnamomi</i> , assessing its long term direct and indirect impacts in the range of priority ecosystems it affects.

Action	Responsible party	Priority	Timeframe	Performance indicators
Action 4.4 Undertake susceptibility/natural resistance screening of priority species.	State and territory governments, research organisations and industry	Medium priority	Medium term	Susceptibility screening of priority species is undertaken at appropriate facilities using plant material from <i>ex situ</i> programs (where available). Infested sites are monitored for resistant individuals or populations to enable the sourcing of material for resistance screening.
Action 4.5 Develop improved techniques for rapid diagnosis of <i>P. cinnamomi</i> infestation, e.g. building on existing efforts for detection via water sampling, testing large volumes of soil (or quarried material) or remote methods such as use of digital multi-spectral imagery.	State and territory governments, research organisations and industry	Very high priority	Medium term	Rapid diagnosis systems for identifying <i>P. cinnamomi</i> infestations are evaluated for use in natural ecosystems. Cost effective and accurate methods for the rapid diagnosis of <i>P. cinnamomi</i> species are available.
Action 4.6 Assess current disease management practices and explore scope for improvement.	Australian Government, state and territory governments and research organisations	High priority	Medium term	Methods to eradicate <i>P. cinnamomi</i> from small, infested sites are identified and assessed for their relative efficacy. The efficacy of phosphite in the control of <i>P. cinnamomi</i> across a range of susceptible ecological communities is determined. The effects of phosphite on non-target species are identified. Alternatives to phosphite for controlling <i>P. cinnamomi</i> are identified and their relative efficacy assessed. This may include, but is not limited to: potential biocontrol options and other chemicals to augment/supplement phosphite.

Action	Responsible party	Priority	Timeframe	Performance indicators
Action 4.7 Develop methods for restoration of priority sites that are degraded by <i>P. cinnamomi</i> .	Australian Government, state and territory governments and research organisations	Medium priority	Ongoing	<p>The efficacy of hygiene protocols for controlling disease spread are assessed and implementation improved (this could include the efficacy of implementation practices).</p> <p>Restoration and revegetation techniques for priority sites degraded by <i>P. cinnamomi</i> are developed over the life of this TAP, using resistant plant species.</p> <p>Resistant species that may provide structure and food sources for priority species are introduced into impacted priority areas.</p>
Action 4.8 Establish repositories for collections of <i>P. cinnamomi</i> cultures and nationally available standards for collection and analysis of <i>P. cinnamomi</i> samples, in order to facilitate research on the genetic basis of resistance and genetic diversity of <i>P. cinnamomi</i> .	Australian Government, state and territory governments and research organisations	Medium priority	Medium term	<p>Cultures of <i>P. cinnamomi</i> are able to be tested against samples available through a complete and accessible national repository for cultures of <i>P. cinnamomi</i> isolated from natural ecosystems.</p> <p>National standard methods are used by laboratories for the collection and analysis of soil, plant and water samples for the presence of <i>P. cinnamomi</i>.</p>

3. Duration, Review, Funding and Implementation

3.1 Duration and review of the plan

Section 279 of the EPBC Act provides for the review of this TAP at any time and requires that it be reviewed by the Minister at intervals of no longer than five years. During the life of the TAP, the Minister's scientific advisory committee (the Threatened Species Scientific Committee), will be provided with updates of actions taken under this TAP to aid them in advising the Minister on the effectiveness of the TAP in abating the key threatening process.

3.2 Funding and implementation

It is important to note that TAPs are not linked directly to any Australian Government funding programs. Each financial year, the Australian Government funds TAP development and implementation as part of a broader budget outcome related to biodiversity conservation (www.environment.gov.au/about/publications/budget/index.html). The Department of the Environment and Energy allocates its annual budget to a range of competing biodiversity conservation priorities. The budget provided by the Department of the Environment and Energy for the implementation of individual TAPs may vary from year to year according to priorities.

The total cost of implementing this TAP cannot be quantified at the time of its writing. Projects that are to be undertaken by the Australian Government will need to be procured in accordance with the Commonwealth Procurement Rules. The cost of individual projects will not be accurately known until a process to test the market (for example to obtain quotes or tenders for those projects) has been undertaken.

The Australian Government recognises that the capacity of each state or territory government to implement this TAP will be dependent on the resources and priorities of that state or territory and the methods of implementation they choose to adopt.

The mining, tourism, horticulture and forestry industries have an interest in protecting biodiversity from the impacts of *P. cinnamomi*. Joint delivery of projects and/or corporate sponsorship from such groups for research and management should be encouraged.

P. cinnamomi occurs in dynamic and evolving cultural landscapes where customary rights and legal and land management changes acknowledge and enable customary activities to take place. Significant opportunities exist to engage and work with Indigenous organisations and custodians of country to achieve the objectives of this TAP.

4. Glossary and Abbreviations

Biodiversity	Variability among living organisms from all sources (including terrestrial, marine and other ecosystems and ecological complexes of which they are part), which includes diversity within species and between species and diversity of ecosystems (Beeton et al., 2006).
Conservation dependent	A native species is eligible to be included in the conservation dependent category of the <i>Environment Protection and Biodiversity Conservation Act 1999</i> at a particular time if, at that time the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered.
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Commonwealth legislation).
Eradication	Application of measures to eliminate an invasive alien species from a defined area.
Key threatening process	As defined in and listed under the EPBC Act a process that threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.
Matters of national environmental significance	<p>Under the EPBC Act, actions that have, or are likely to have, a significant impact on a matter of national environmental significance require approval from the Australian Government Minister for the Environment (the Minister). The Minister will decide whether assessment and approval is required under the EPBC Act.</p> <p>The eight matters of national environmental significance protected under the EPBC Act are:</p> <ul style="list-style-type: none">• world heritage properties• national heritage places• wetlands of international importance (listed under the Ramsar Convention)• listed threatened species and ecological communities• migratory species protected under international agreements• Commonwealth marine areas

- the Great Barrier Reef Marine Park
- nuclear actions (including uranium mines).

Performance indicator	A criterion or measure that provides information on the extent to which a policy, program or initiative is achieving its outcomes.
Priority biodiversity asset	Includes matters of national environmental significance listed under the EPBC Act and other plants, animals and communities prioritised under Objective 1 of this TAP for protection or remediation.
Threat abatement plan	Under the EPBC Act (Section 268), a plan providing for the research, management, and any other actions necessary to reduce the impact of a listed key threatening process on a threatened species or ecological community.
Threatened species	Species under the EPBC Act listed as critically endangered, endangered, vulnerable or conservation dependent.

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Appendix A

Threatened flora species known to be susceptible to *Phytophthora cinnamomi*

Species shown in Appendix A are listed as threatened under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and are known to be susceptible to disease from *P. cinnamomi* infection.

Susceptibility information is from O'Gara et al. (2005a), which compiles published material, unpublished records and observations of individual researchers on the responses of native plants to *P. cinnamomi*. For further detail relating to native species not listed under the EPBC Act, please refer to O'Gara et al. 2005a.

Several additional EPBC listed species were confirmed as susceptible by Barrett et al. (2008), Kueh et al. (2012) and Tim Rudman pers. comm. (2012).

EPBC Act status: CE=critically endangered; E=endangered; V= vulnerable

Susceptible species	EPBC Act status	State/territory
ANTHERICACEAE		
<i>Borya mirabilis</i>	E	Vic.
ASTERACEAE		
<i>Olearia pannosa</i> subsp. <i>pannosa</i>	V	SA
ARAUCARIACEAE		
<i>Wollemia nobilis</i>	E	NSW
CASUARINCEAE		
<i>Allocasuarina fibrosa</i>	V	WA
EPACRIDACEAE		
<i>Andersonia axilliflora</i>	E	WA
<i>Andersonia pinaster</i>	V	WA

Susceptible species	EPBC Act status	State/territory
<i>Epacris apsleyensis</i>	E	Tas.
<i>Epacris barbata</i>	E	Tas.
<i>Epacris exserta</i>	E	Tas.
<i>Epacris glabella</i>	E	Tas.
<i>Epacris graniticola</i>	CE	Tas.
<i>Epacris grandis</i>	E	Tas.
<i>Epacris limbata</i>	CE	Tas.
<i>Epacris stuartii</i>	CE	Tas.
<i>Epacris virgata</i>	E	Tas.
<i>Leucopogon gnaphaloides</i>	E	WA
<i>Leucopogon marginatus</i>	E	WA
<i>Leucopogon obtectus</i>	E	WA
<i>Sphenotoma drummondii</i>	E	WA
FABACEAE		
<i>Daviesia bursarioides</i>	E	WA
<i>Daviesia euphorbioides</i>	E	WA
<i>Daviesia glossosema</i>	CE	WA
<i>Daviesia megacalyx</i>	E	WA
<i>Daviesia microcarpa</i>	E	WA
<i>Daviesia pseudaphylla</i>	E	WA

Susceptible species	EPBC Act status	State/territory
<i>Daviesia speciosa</i>	E	WA
<i>Gastrolobium papilio</i>	E	WA
LAMIACEAE		
<i>Prostanthera eurybioides</i>	E	SA
<i>Prostanthera marifolia</i>	CE	NSW
MYRTACEAE		
<i>Darwinia collina</i>	E	WA
<i>Darwinia meeboldii</i>	V	WA
<i>Darwinia oxylepis</i>	E	WA
<i>Darwinia squarrosa</i>	V	WA
<i>Eucalyptus imlayensis</i>	E	NSW/ACT
<i>Verticordia carinata</i>	V	WA
<i>Verticordia densiflora</i> var. <i>pedunculata</i>	E	WA
PROTEACEAE		
<i>Adenanthos dobagii</i>	E	WA
<i>Adenanthos ellipticus</i>	V	WA
<i>Adenanthos eyrei</i>	E	WA
<i>Adenanthos pungens</i> subsp. <i>effusus</i>	E	WA
<i>Adenanthos pungens</i> subsp. <i>pungens</i>	V	WA

Susceptible species	EPBC Act status	State/territory
<i>Adenanthos velutinus</i>	E	WA
<i>Banksia anatona</i>	CE	WA
<i>Banksia aurantia</i>	CE	WA
<i>Banksia brownii</i>	E	WA
<i>Banksia cuneata</i>	E	WA
<i>Banksia goodii</i>	V	WA
<i>Banksia mimica</i>	E	WA
<i>Banksia montana</i>	E	WA
<i>Banksia nivea</i> subsp. <i>uliginosa</i>	E	WA
<i>Banksia oligantha</i>	E	WA
<i>Banksia serratuloides</i> subsp. <i>perissa</i>	CE	WA
<i>Banksia squarrosa</i> subsp. <i>argillacea</i>	V	WA
<i>Banksia verticillata</i>	V	WA
<i>Conospermum hookeri</i>	V	Tas.
<i>Conospermum undulatum</i>	V	WA
<i>Grevillea batrachoides</i>	E	WA
<i>Grevillea calliantha</i>	E	WA
<i>Grevillea christinae</i>	E	WA
<i>Grevillea elongata</i>	E	WA

Susceptible species	EPBC Act status	State/territory
<i>Grevillea flexuosa</i>	V	WA
<i>Grevillea infundibularis</i>	E	WA
<i>Grevillea involucrata</i>	E	WA
<i>Grevillea maccutcheonii</i>	E	WA
<i>Grevillea maxwellii</i>	E	WA
<i>Grevillea murex</i>	E	WA
<i>Grevillea scapigera</i>	E	WA
<i>Grevillea williamsonii</i>	E	Vic.
<i>Hakea megalosperma</i>	V	WA
<i>Isopogon uncinatus</i>	E	WA
<i>Lambertia echinata</i> subsp. <i>echinata</i>	E	WA
<i>Lambertia echinata</i> subsp. <i>occidentalis</i>	E	WA
<i>Lambertia fairallii</i>	E	WA
<i>Lambertia orbifolia</i>	E	WA (2 subsp WA)
<i>Lomatia tasmanca</i>	CE	Tas.
<i>Persoonia micranthera</i>	E	WA
<i>Petrophile latericola</i>	E	WA
RHAMNACEAE		
<i>Pomaderris halmaturina</i> subsp. <i>halmaturina</i>	V	SA

Susceptible species	EPBC Act status	State/territory
RUTACEAE		
<i>Asterolasia phebaloides</i>	V	SA, Vic.
<i>Boronia revoluta</i>	E	WA
<i>Correa calycina</i>	V	SA
<i>Leionema ralstonii</i>	V	NSW/ACT
<i>Phebalium daviesii</i>	CE	Tas.
THYMELAEACEAE		
<i>Pimelea pagophila</i>	V	Vic.
TREMANDRACEAE		
<i>Tetratheca gunnii</i>	CE	Tas.
WINTERACEAE		
<i>Tasmannia purpurascens</i>	V	NSW/ACT
XANTHORRHOEACEAE		
<i>Xanthorrhoea arenaria</i>	V	Tas
<i>Xanthorrhoea bracteata</i>	E	Tas.

Appendix B

Threatened ecological communities listed under the EPBC Act that may be impacted by *Phytophthora cinnamomi*

Threatened ecological communities listed under the EPBC Act can be found at:

<http://www.environment.gov.au/biodiversity/threatened/communities.html>

This list was compiled on the basis of threatened ecological communities occurring within the climatic zone in which conditions for *P. cinnamomi* are favourable. The list was refined in consultation with state agencies.

EPBC Act status: CE=critically endangered; E=endangered; V= vulnerable

Ecological communities listed under the EPBC Act	EPBC Act status	State/territory
Arnhem Plateau sandstone shrubland complex	E	NT
Banksia Woodlands of the Swan Coastal Plain ecological community	E	WA
Blue Gum high forest of the Sydney Basin Bioregion	CE	NSW
Broad leaf tea-tree (<i>Melaleuca viridiflora</i>) woodlands in high rainfall coastal north Queensland	E	Qld
Claypans of the Swan Coastal Plain	CE	WA
Coastal Upland Swamps in the Sydney Basin Bioregion	E	NSW
<i>Corymbia calophylla</i> - <i>Kingia australis</i> woodlands on heavy soils of the Swan Coastal Plain	E	WA
<i>Corymbia calophylla</i> - <i>Xanthorrhoea preissii</i> woodlands and shrublands of the Swan Coastal Plain	E	WA
Cumberland Plain shale woodlands and shale-gravel transition forest	CE	NSW

Ecological communities listed under the EPBC Act	EPBC Act status	State/territory
Eastern Stirling Range montane heath and thicket	E	WA
Eastern Suburbs Banksia scrub of the Sydney Region	E	NSW
Eucalypt Woodlands of the Western Australian Wheatbelt	CE	WA
Gippsland Red Gum (<i>Eucalyptus tereticornis</i> subsp. <i>mediana</i>) grassy woodland and associated native grassland	CE	Vic.
Grassy Eucalypt woodland of the Victorian Volcanic Plain	CE	Vic.
Lowland grassy woodland in the South East Corner Bioregion	CE	NSW/ACT/Vic.
Lowland rainforest of subtropical Australia	CE	Qld/NSW
Monsoon vine thickets on the coastal sand dunes of Dampier Peninsula	E	WA
New England Peppermint (<i>Eucalyptus nova-anglica</i>) grassy woodlands	CE	Qld/NSW
Peppermint Box (<i>Eucalyptus odorata</i>) grassy woodland of South Australia	CE	SA
Scott River ironstone association	E	WA
Sedgeland in Holocene dune swales of the southern Swan Coastal Plain	E	WA
Shale/sandstone transition forest	E	NSW
Shrublands and woodlands of the eastern Swan Coastal Plain	E	WA
Shrublands on southern Swan Coastal Plain ironstones	E	WA
Silurian limestone Pomaderris shrubland of the South East Corner and Australian Alps Bioregions	E	Vic.
Swamp Tea-tree (<i>Melaleuca irbyana</i>) forest of south-east Queensland	CE	Qld

Ecological communities listed under the EPBC Act	EPBC Act status	State/territory
Swamps of the Fleurieu Peninsula	CE	SA
Temperate highland peat swamps on sandstone	E	NSW/Vic.
Turpentine-Ironbark Forest in the Sydney Basin Bioregion	CE	NSW
Weeping Myall-Coobah-Scrub Wilga shrubland of the Hunter Valley	CE	NSW
Western Sydney dry rainforest and moist woodland on shale	CE	NSW
White Box-Yellow Box-Blakely's Red Gum grassy woodland and derived native grassland	CE	Qld/ NSW/ Vic.