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THREAT ABATEMENT PLAN

for competition and land degradation by unmanaged goats

2008

Department of the Environment, Water, Heritage
and the Arts

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Contents

1. Introduction

This threat abatement plan (TAP) establishes a national framework to guide and coordinate Australia's response to the impacts of unmanaged goats (*Capra hircus*) on biodiversity. It identifies the research, management and other actions needed to ensure the long-term survival of native species and ecological communities affected by competition and land degradation caused by unmanaged goats. It replaces the TAP for competition and land degradation by feral goats published in 1999 (EA 1999a).

This plan should be read in conjunction with the publication *Background document for the threat abatement plan for competition and land degradation by unmanaged goats* (DEWHA 2008). The background document provides information on unmanaged goat characteristics, biology and distribution; impacts on environmental, economic, social and cultural values; and current management practices and measures.

1.1 Threat abatement plans

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the Australian Government develops TAPs and facilitates their implementation. To progress the main strategic development actions, the Department of the Environment, Water, Heritage and the Arts (DEWHA) assesses the potential for partnerships and co-investments with other government agencies, industry and other stakeholders. An important part of implementation of the TAP is ensuring that knowledge of improved abatement methods is disseminated to potential users.

Mitigating the threat of invasive species is not simply a matter of providing better technical solutions, such as improved baits for feral animal control. It also involves understanding and addressing social and economic factors; for example, through supporting the efforts of private landholders and leaseholders to manage invasive species on their lands for biodiversity conservation and primary production. In addition, research and development programs for controlling vertebrate pest species need to integrate interests of both primary production and environmental conservation.

Regional natural resource management plans and site-based plans provide the best scale and context for developing operational plans to control invasive species. They allow primary production and environmental considerations to be jointly addressed, and control to be integrated across the local priority vertebrate pests within the scope of other natural resource management priorities.

The national coordination of pest animal control activities occurs under the Australian Pest Animal Strategy, released in 2007 by the Natural Resource Management and Primary Industries Ministerial Councils. The Vertebrate Pests Committee, comprising representatives from all Australian, state and territory governments, has responsibility for implementation of the strategy. This TAP provides guidance for abating the impacts of unmanaged goats within that broader context.

1.2 Threat abatement plan for unmanaged goats

1.2.1 The threat

Goats are found across approximately 2 million square kilometres of Australia. They are present in all states, the Australian Capital Territory and some offshore islands, including islands that are part of the Northern Territory. However, unmanaged goats are not found on the mainland of the Northern Territory. Further details about distribution and abundance are in the accompanying background document (DEWHA 2008).

The intensity of goat management varies widely. In the agricultural zone, goats are typically more intensively farmed and tightly constrained by high fencing. In the pastoral zone, goats on leasehold or private property may be under varying levels of management.

The focus of this TAP is to minimise the impacts of goats wherever they affect biodiversity. Goats can be managed for productive purposes on private and leasehold lands in a total grazing pressure context, while still maintaining biodiversity values (Pearce et al. 1998). The focus of this plan is to abate the impacts of goats where they are not actively managed, while allowing for the responsible farming of goats. The plan therefore refers mainly to the impacts of 'unmanaged goats.'

Under this plan, 'unmanaged goats' are goats that are free-living and not subject to livestock husbandry but may be 'owned' in the sense that access for harvesting or control is determined by the owner or occupier of the land. This is in contrast to 'managed' goats, which are those held under some combination of animal husbandry (owned, identified, restrained, managed for population structure and density, and receive welfare). Some goats may have one or more of the characteristics of managed goats, but in all other respects can be indistinguishable from unmanaged animals with no husbandry (after Forsyth and Parkes 2004, who explains the distinction but uses the terms feral and domestic goats).

Unmanaged goats can be a serious pest because of their ability to severely affect native flora and fauna. They are recognised internationally as a serious pest, appearing in the World Conservation Union's list of the 100 worst invasive species (Lowe et al. 2000). Competition and land degradation by feral goats is listed as a key threatening process under the EPBC Act. Unmanaged goats are a threat to a number of native species (see Appendix A), although impacts from goat competition and land degradation are not restricted to these species.

This TAP has been put into place as a feasible, effective and efficient way to abate the threat of competition and land degradation by unmanaged goats.

1.2.2 The impacts

Characteristics of goats that help to explain their invasiveness and impacts are their diet and fecundity. As generalist herbivores, they can colonise a wide range of habitats. With two breeding seasons a year, and twins and triplets common, goat populations can increase by up to 50 per cent a year under favourable conditions (Mahood 1985, Maas and Choquenot 1995, Parkes et al. 1996, Fleming 2004).

Similarly to other grazing animals, unmanaged goats can affect native flora and fauna by grazing on native vegetation, thereby preventing regeneration (Harrington 1979, Harrington 1986, Greene et al. 1998); by overgrazing, which causes soil erosion (Bayne et al. 2004); by competing for food and shelter; by introducing weeds through seeds carried in their dung; and by fouling waterholes.

1.2.3 Managing the threat

Control of unmanaged goats relies on a range of approaches. The main techniques suitable for broadscale

control are mustering (mainly suitable in areas of flat terrain), trapping (mainly suitable in arid or semiarid areas where water sources are limited) and aerial shooting (useful in inaccessible terrain). Eradication from offshore islands (or from mainland areas that have similarly isolated populations) is feasible and has been achieved by various methods. Other pressures on goats, such as predation by dingoes, may also reduce their numbers.

In some areas of broadacre grazing it can be difficult to differentiate between managed and unmanaged herds. In these areas, the impacts from goats need to be considered as a component of the overall grazing pressure from both introduced livestock and from native species. Best practice management in these 'blended' situations (or where unmanaged goats alone are present) should involve reduction of the threat to native species that may be affected by competition and land degradation from goats. The varying contexts in which goats are found reinforces the need for governments, the goat industry and other key stakeholders to work together to abate the impact on biodiversity from goats.

1.2.4 The review of the 1999 TAP

In accordance with the requirements of the EPBC Act, the original TAP for feral goat competition and land degradation (EA 1999a) was reviewed in 2004–05 by the Bureau of Rural Sciences (BRS) (Hart 2005) as part of a broader review encompassing the original TAPs for cats (EA 1999b), foxes (EA 1999c) and rabbits (EA 1999d).

The BRS review found that it was difficult to accurately determine the extent to which the goat TAP had reduced the impacts of goats on biodiversity. This reflects the current paucity of nationally consistent data on the ranges and densities of goats and their impacts, and the difficulties of linking outcomes in goat population changes to the outputs of the TAP. The invasive species indicator data to be produced under the National Monitoring and Evaluation Framework (NRMMC) should improve the availability of continental overview data over the next year or so.

The BRS surveyed a broad range of stakeholders and assessed a range of projects commissioned by the Department of Environment and Heritage (now the Department of the Environment, Water, Heritage and the Arts) that were developed under the auspices of the existing TAPs. This has helped to identify actions that will need to be initiated or continued into the future. The review concluded, however, that the goat-related projects that were assessed had positively contributed to reducing the impacts of goats.

The BRS review proposed a number of changes to the actions found in the original TAP, but recommended that the objectives remain substantially unchanged. The review suggested that the implementation of the revised goat TAP should give priority to improved national engagement, integrated pest animal control, flexibility in implementation, setting priorities for research, follow-through with research and development, and establishment of a new advisory panel for vertebrate TAPs. The review also recommended that revised plans include measures to enhance existing processes through, for example, regional processes; control and monitoring techniques that support on-ground management; and monitoring of key projects according to national protocols.

This document replaces the 1999 TAP. It incorporates the knowledge gained in the intervening years and has been modified in line with recommendations from the review. The TAP aims to guide the responsible use of public resources and the best outcome for native species and ecological communities threatened by competition and land degradation by unmanaged goats. The plan seeks to achieve these outcomes by recognising the opportunities and limitations that exist, and ensuring that field experience and research are used in dealing with the impacts from unmanaged goats. The activities and priorities under the TAP will need to adapt to changes as they occur.

1.2.5 Involvement of stakeholders

The successful implementation of this TAP will depend on a high level of cooperation between landholders,

community groups, local government, state and territory conservation and pest management agencies, and the Australian Government and its agencies. Success will depend on all participants assessing the impact of unmanaged goats and allocating adequate resources to achieve effective on-ground control of unmanaged goats at critical sites, improve the effectiveness of control programs, and measure and assess outcomes. Various programs in natural resource management, at national, state and regional levels, will assist stakeholders to make significant contributions to implementing the plan.

2. Objectives and actions

The goal of this TAP is to minimise the impact of unmanaged goat competition and land degradation on biodiversity in Australia and its territories by:

- protecting affected native species and ecological communities, and
- preventing further species and ecological communities from becoming threatened.

To achieve this goal, the plan has five main objectives, developed through the review of the previous TAP (Hart 2005) and consultation with experts. These objectives are to:

1. prevent unmanaged goats occupying new areas in Australia and eradicate them from high-conservation-value 'islands'
2. promote the maintenance and recovery of native species and ecological communities that are affected by competition and land degradation by unmanaged goats
3. improve knowledge and understanding of unmanaged goat impacts and interactions with other species and other ecological processes
4. improve the effectiveness, target specificity and humaneness of control options for unmanaged goats, and
5. increase awareness of all stakeholders of the objectives and actions of the TAP, and of the need to control unmanaged goats.

Each objective is accompanied by a set of actions, which, when implemented, will help to achieve the goal of the plan. Performance indicators have been established for each objective. Progress will be assessed by determining the extent to which the conditions set in the performance indicators have been met.

The sections below provide background on each objective, followed by a table listing the actions required to meet the objective. Twenty actions have been developed to meet the five objectives.

Priorities for each action are given in the tables below, categorised as 'very high', 'high' or 'medium'. Each action has also been assigned a timeframe within which the outcome could be achieved once the action has commenced. Timeframes are categorised as short term (i.e. within three years), medium term (i.e. within three to five years) or long term (i.e. five years or beyond).

☐ **Objective 1**

Prevent unmanaged goats occupying new areas in Australia and eradicate them from high-conservation-value 'islands'

Key actions for Objective 1 include identifying 'islands' of high conservation value, ranking the risk to such areas posed by unmanaged goats, and developing and implementing management plans to protect such areas from them. The actions are designed to prevent unmanaged goats from extending their range in Australia, and to remove them from high-conservation-value 'islands' if eradication is feasible. The actions focus on off-shore islands and on mainland 'islands' that are isolated or currently do not have unmanaged goats. All the actions are of high to very high priority and could be achieved within three to five years.

Action 1.1 focuses on collating data on conservation values of island areas, the likelihood of significant biodiversity impacts from unmanaged goats, and the risk that competition and land degradation from them will become a threat in these areas. DEWHA is establishing a national database of introduced animals across Australian offshore islands that will complement this work.

Action 1.2 develops contingency plans for preventing, monitoring and, if an incursion occurs, containing and eradicating unmanaged goats in areas with high conservation values. Action 1.3 implements these plans. All planning and implementation work would recognise that unmanaged goats are one of many pests facing land managers, and therefore would be undertaken within the context of integrated management activities.

Action 1.4 involves eradicating established populations of unmanaged goats from those 'islands' considered to be of high conservation value, depending on feasibility and cost-effectiveness. The identification of any areas for eradication of goats should closely involve local communities and landholders, including those with an economic interest in those herds.

Although not included as an action, genetic characterisation of existing populations should be considered as it may help identify sources and/or mechanisms of invasion, and thus help to prevent new invasions in the future.

Performance indicators

- No further establishments of unmanaged goats in goat-free areas of high conservation value.
- Successful eradication of isolated populations of unmanaged goats where this is attempted.
- Increased populations of affected native species in areas from which unmanaged goats, and other invasive species, have been eradicated.

Action	Priority and timeframe
1.1 Collate data on offshore islands, and on isolated mainland 'islands', assess their conservation value, the likelihood of significant biodiversity impacts from unmanaged goats, and if there are no goats, rank the level of risk from them being introduced and establishing populations.	High priority, short term
1.2 Develop management plans to prevent, monitor and, if incursions occur, contain and eradicate any incursion by unmanaged goats, for 'islands' with high conservation values.	Very high priority, undertake in short term, monitor over long term
1.3 Implement management plans for high-conservation-value 'islands', including prevention and monitoring actions, and containment or eradication actions if incursions occur.	Very high priority, medium term
1.4 Eradicate established populations of unmanaged goats from 'islands' with high conservation values where this is cost-effective, feasible and a high conservation priority.	Very high priority, undertake in short term, monitor over medium term

☐ Objective 2

Promote the maintenance and recovery of native species and ecological communities that are affected by competition and land degradation by unmanaged goats

Key actions for Objective 2 include identifying priority areas for investment in controlling unmanaged goats; implementing and supporting regional control programs; and applying incentives for promoting and maintaining control programs adjacent to the priority areas. Actions 2.1–2.3 focus programs in goat control on the maintenance and recovery of native species and ecological communities affected by competition and land degradation from unmanaged goats. All these actions are of high or very high priority.

Broadscale control of unmanaged goats in Australia is not feasible using the methods currently available. Therefore, it is necessary to identify priority areas for control based on scientific evidence of the significance of the population of native species or the ecological community affected and the degree of impact posed by unmanaged goats relative to other impacts. In addition, the cost-effectiveness of a control program and the feasibility of effective remedial action must be considered. These activities are covered by Action 2.1. Identification of priority areas can involve mapping the distribution of susceptible species, high-risk habitats and unmanaged goats to produce a national overview of priority regions (e.g. using the approach outlined in Dickman [1996] and NSW NPWS [2003]).

Once priority areas for investment have been identified, the next step is to implement regional control programs, as described in Action 2.2. Organisations implementing control programs will be encouraged to focus on areas where the control of unmanaged goats will help to reduce the threat to native species. The success of control programs should be monitored, applying national monitoring protocols (see Action 3.1) as soon as they are available.

It is important to promote goat control in priority areas and in adjacent areas, to prevent reinvasion. Action 2.3 focuses on applying new and existing incentives for such actions on private and leasehold lands.

Performance indicators

- Priority areas, where goat control is required to protect important affected flora and fauna, have been identified and are a focus for unmanaged goat control programs.
- The effectiveness of programs to control unmanaged goats is measured through pre and post-control monitoring of unmanaged goat populations and of key native species.

Action	Priority and timeframe
2.1 Identify priority areas to control unmanaged goats based on: • the significance of the population of the affected native species or of the ecological community • the degree of threat posed by unmanaged goats to species and ecological communities relative to other threats • the cost-effectiveness of maintaining unmanaged goat populations below an identified 'damage threshold' in the region, and • the feasibility of effective remedial action	Very high priority, short term
2.2 Conduct and monitor regional goat control, through new or existing programs, in priority areas identified in Action 2.1.	High priority, short term

2.3 Apply incentives to promote and maintain on-ground control of unmanaged goats on private or leasehold lands within or adjacent to priority sites identified in Action 2.1.	High priority, long term

☐ Objective 3

Improve knowledge and understanding of unmanaged goat impacts and interactions with other species and other ecological processes

Key actions for Objective 3 include developing simple, cost-effective methods for monitoring impacts; improving knowledge of interactions between unmanaged goats and key native species, and between unmanaged goats, livestock, rabbits, macropods and wild dogs; and identifying unintended effects of controlling unmanaged goats in isolation from other activities. Actions 3.1–3.4 focus on ensuring that goat control programs do not lead to unintended impacts, and that control activities are targeted strategically through better understanding of the impacts of unmanaged goats and their interactions with other species. These actions are mainly of high to very high priority, and most should be achieved in the short to medium term.

To determine the effectiveness of goat control programs, Action 3.1 is to develop simple, cost-effective methods for monitoring the impact of this invasive species on affected species and ecological processes (e.g. nutrient cycles and fire regimes) relative to other sources of impact, such as wild rabbits and domestic livestock. Monitoring methods need to be reliable for different densities of both unmanaged goats and the native species they affect through competition and land degradation. Areas for investigation include the feasibility and practicality of individual identification of unmanaged goats by genotyping scats or hairs, to help estimate abundance, particularly at low densities.

Interactions between unmanaged goats and other species need to be considered when undertaking control programs. Action 3.2 is to investigate interactions between goats, livestock, rabbits, macropods and wild dogs. This will help determine optimal approaches to integrated management of these species in the rangelands. For example, certain fences used to contain goats can also exclude wild dogs. Action 3.3 is to identify any unintended effects that controlling unmanaged goats may have if it is not integrated with other management activities, such as weed outbreaks or increases in other grazers.

One of the most important actions is Action 3.4, which is to establish the relationship between density of unmanaged goats and damage and benefits in different ecosystems.

Performance indicators

- Reliable monitoring techniques have been developed for unmanaged goats.
- Control of unmanaged goats is better integrated with control of other vertebrate pests.
- The unintended effects of programs to control unmanaged goats are minimised.

Action	Priority and timeframe
3.1 Develop simple and cost-effective methods for assessing and monitoring the impact of unmanaged goats relative to other sources of impact, including reliable methods for monitoring their numbers and their effects at different densities on key native species.	High priority, short term
3.2 Investigate interactions between unmanaged goats, other livestock species, rabbits, macropods and wild dogs to determine optimal approaches to integrated management of these species in the rangelands.	High priority, medium to long term
3.3 Identify any unintended effects that controlling unmanaged goats may have if conducted in isolation from other management activities.	High priority, medium term
3.4 Investigate the relationship between unmanaged goat density and damage and benefits in different ecosystems.	High priority, medium term

☐ **Objective 4**

Improve the effectiveness, target specificity, integration and humaneness of control options for unmanaged goats

Key actions for Objective 4 include improving control methods, strategic use of exclusion fencing, increasing use of control methods by land managers, increasing adoption of standard control methods, promoting commercial use approaches that complement conservation objectives, and investigating the eradication of isolated populations through the use of integrated control methods. Actions 4.1–4.7 focus on improving options to control unmanaged goats through better use of existing techniques and development of new techniques, including those for monitoring success of control in the field. These actions are of medium to high priority; some are already partially achieved, and most could be achieved within the next three to five years.

Total grazing management systems incorporating self-mustering traps have, in some regions, played a useful role in controlling goat numbers. Trapping groups of goats around watering points can be an effective and efficient control technique (Harrington 1982), but in areas of high rainfall, trapping is effective only in dry times when goats are obliged to find water and there is no access to alternative water sources. Action 4.1 includes research into the potential of bore capping and new technologies, such as 'machine vision' species recognition, to improve the effectiveness of waterpoint trapping.

Action 4.2 is to research the potential drawbacks of toxins used to poison unmanaged goats; for example, their potential to affect non-target species.

Action 4.3 is to test and disseminate information on exclusion fencing, such as that contained in a recent review (Long and Robley 2004). The review authors were unable to locate any exclusion fences (except for small experimental exclosures) designed to exclude unmanaged goats from conservation areas. Goats will eventually breach most fences; therefore, fencing is often regarded as a tactical weapon to facilitate control of

unmanaged goats rather than a tool for achieving complete exclusion (Parkes et al. 1996).

To improve the effectiveness of control programs, Action 4.4 is to develop training programs to help land managers adopt and evaluate control methods appropriate for local conditions and determine in what circumstances and times they should be used.

To ensure that goat management follows best practice, Action 4.5 is to continue to promote the adoption and adaptation of the relevant model codes of practice and standard operating procedures for the humane management of goats (Sharp and Saunders 2004), including their recognition as a reference under the National Competency Standards for Vertebrate Pest Management (National Training Information Service 2007). This should be done in conjunction with the national feral livestock code of practice (CSIRO 1995).

Action 4.6 is to promote commercial approaches that complement conservation objectives. One possible option could be supporting landholders in key areas to reduce unmanaged goat densities to levels below those that are commercially viable for harvesting.

Various control techniques, such as trapping, aerial and ground shooting, and use of Judas goats can be effective in controlling unmanaged goats. Action 4.7 is to investigate the potential for integrating such techniques to eradicate unmanaged goats from offshore islands or areas of the mainland with isolated unmanaged goat populations.

Performance indicators

- Increased proportion of goat control programs use 'best-practice' techniques.
- Increased use of exclusion fencing in situations where it is considered to be more cost-effective than ongoing control of unmanaged goats and to protect critically endangered species.
- Increased adoption and adaptation of the model codes of practice and standard operating procedures for humane management of unmanaged goats, including their recognition as a reference under the National Competency Standards for Vertebrate Pest Management.

Action	Priority and timeframe
4.1 Investigate opportunities to improve self-mustering trap systems that operate within a scheme of total grazing management, as well as investigate the potential of bore capping and new technologies to increase the effectiveness of waterpoint trapping.	High priority, short term
4.2 Assess goat toxins for undesirable side-effects, such as off-target species impacts.	Medium priority, long term
4.3 Test and disseminate information on exclusion fence designs regarding their cost-effectiveness for particular habitats or topography.	High priority, short term
4.4 Develop training programs to help land managers identify locally appropriate control methods and the circumstances and times in which to apply them.	High priority, short term
4.5 Continue to promote the adoption and adaptation of the model codes of practice and standard operating procedures for humane management of goats, in	High priority, long term

conjunction with the national feral livestock code of practice	
4.6 Promote commercial use approaches that complement conservation objectives.	Medium priority, long term
4.7 Investigate the potential to integrate a range of conventional control techniques to eradicate isolated or island populations of unmanaged goats.	High priority, medium term

☐ Objective 5

Increase awareness of all stakeholders of the objectives and actions of the TAP, and of the need to control unmanaged goats

Key actions for Objective 5 focus on ensuring that the TAP actions, and the need to manage goats, are communicated to interested parties by preparing and distributing extension materials. Working with primary producers of goats will be important to minimise the risk of recruitment of their goat stock into unmanaged populations, particularly outside the rangelands, and to finding approaches that take into account their economic interests in goat harvesting.

The promotion of extension materials as noted in Action 5.1 will help develop knowledge and understanding of the 18 actions listed in Objectives 1–4 of the TAP, of the techniques used in controlling unmanaged goats, and why competition by feral goats is listed as a key threatening process. Action 5.2 is to monitor the economic costs of control activities and compare these to the environmental benefits gained through control of unmanaged goats, using information from the actions under Objectives 2 and 3.

Performance indicators

- Widespread use of current 'best practice' techniques in control of unmanaged goats.
- Greater awareness in the rural community about issues surrounding unmanaged goats.
- Increased awareness of the TAP actions and objectives.

Action	Priority and timeframe
5.1 Promote: • broad understanding of the threat to biodiversity posed by unmanaged goats and support for their control • basic protocols for effective control of unmanaged goats in conservation areas and farmlands including, for example, with primary producers of goats • the importance of competition and land degradation by unmanaged goats as a key threatening process • understanding and adoption of the actions to be undertaken under this plan • the use of humane and cost-effective goat control methods, and • the involvement of the community in controlling unmanaged goats.	High priority, short term
5.2 Compare the economic costs and environmental benefits of control	Medium priority, medium term

activities.	

3. Duration, cost, implementation and evaluation of the plan

3.1 Duration and cost of the plan

This plan reflects the fact that the threat abatement process is likely to be ongoing, as unmanaged goats are established in Australia. In most cases, the ongoing costs of controlling unmanaged goats will be high. Current options for control in mainland areas are mustering, trapping and aerial shooting. All of these are expensive, time consuming and not suitable for broadscale implementation.

Investment in many of the TAP actions will be determined by the level of resources that stakeholders commit to management of the problem. The total cost of implementation therefore cannot be quantified at the time of writing. However, overall control costs for unmanaged goats have been estimated at $2 million per year in Australia (McLeod 2004), with labour costs of up to $0.9 million in the six-year period from 1998 to 2003 (Reddiex and Forsyth 2004).

This TAP provides a framework for undertaking targeted priority actions. Budgetary and other constraints may affect the achievement of the objectives of this plan, and as knowledge changes, proposed actions may be modified over the life of the plan. Australian Government funds may be available to implement key national environmental priorities, such as relevant actions listed in this plan and actions identified in regional natural resource management plans.

3.2 Implementing the plan

DEWHA will work with other Australian Government agencies, state and territory governments, and national and regional industry and community groups, to facilitate the implementation of the plan. There are many different stakeholder interests and perspectives to take into account in managing goats. For example, the views of Indigenous communities, pastoralists and environment groups need to be fully considered. It will be important to consult and involve the range of stakeholders in implementing the actions in this plan.

The Australian Government will implement the plan as it applies to Commonwealth land.

DEWHA will support a TAP implementation team to assist and advise on the implementation of the plan. The team will draw on expertise in vertebrate pest management from state and territory agencies, and non-government organisations.

This TAP will operate under the overarching framework of the Australian Biosecurity System for Primary Production and the Environment (AusBIOSEC) and in the context of the Australian Pest Animal Strategy, both of which aim to reduce the impacts of invasive species on native species and ecosystems.

3.3 Evaluating implementation of the plan

It will be difficult to assess directly the effectiveness of the plan in abating the impacts of unmanaged goats on Australia's biodiversity, given the broad range of stakeholders involved in their control. However, the Natural Resource Management Monitoring and Evaluation Framework (NRMMC 2003) established a program to provide national information about resource condition on a range of biophysical matters,

including threats from vertebrate species such as unmanaged goats. As part of this work, a range of indicators will provide information on the extent of the impact of priority vertebrate species on biodiversity, as well as national trends on their distribution and abundance.

Appendix A: Species affected by unmanaged goats

The species in the table below may be adversely affected by competition and land degradation from unmanaged goats (that is, there is scientific proof, anecdotal evidence or the potential for impact). The threatened species included are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The list is indicative and not comprehensive.

Information for species listed under the EPBC Act is available from the Species Profile and Threats Database: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl.

Table A1: Threatened species that may be adversely affected by unmanaged goats

Type/category	Scientific name	Common name	Current status
Listed threatened species that may be adversely affected by unmanaged goats			
Birds	*Amytornis barbatus barbatus*	Grey grasswren (bulloo)	Vulnerable
	Amytornis textilis modestus	Thick-billed grasswren (eastern)	Vulnerable
	Calyptorhynchus lathami halmaturinus	Glossy black-cockatoo (South Australian), glossy black-cockatoo (Kangaroo Island)	Endangered
	Gallirallus sylvestris (listed as *Tricholimnas sylvestris*)	Lord Howe woodhen	Vulnerable
	Leipoa ocellata	Malleefowl	Vulnerable
	Lagostrophus fasciatus fasciatus	Banded hare-wallaby, marnine, munning	Vulnerable
	Malurus leucopterus leucopterus	White-winged fairy-wren (Dirk Hartog Island), Dirk Hartog black-and-white fairy-wren	Vulnerable
	Pterodroma neglecta neglecta	Kermadec petrel (western)	Vulnerable
Mammals	*Petrogale lateralis lateralis*	Black-flanked rock-wallaby	Vulnerable

Type/category	Scientific name	Common name	Current status
	Petrogale penicillata	Brush-tailed rock-wallaby	Vulnerable
	Petrogale xanthopus xanthopus	Yellow-footed rock-wallaby (SA and NSW)	Vulnerable
Insects	*Paralucia spinifera*	Bathurst copper butterfly, purple copper butterfly, Bathurst copper, Bathurst copper wing, Bathurst-Lithgow copper, purple copper	Vulnerable
Plants	*Acacia ammophila*		Vulnerable
	Acacia araneosa	Spidery wattle, Balcanoona wattle	Vulnerable
	Acacia curranii	Curly-bark wattle	Vulnerable
	Acacia macnuttiana	McNutt's wattle	Vulnerable
	Acacia menzelii	Menzel's wattle	Vulnerable
	Acacia pycnostachya	Bolivia wattle	Vulnerable
	Acacia unguicula		Critically endangered
	Arachnorchis arenaria (listed as *Caledenia arenorchis*)		Endangered
	Arachnorchis lowanensis	Wimmera spider-orchid	Endangered
	Astrotricha roddii		Endangered
	Bertya opponens (listed as *Bertya* sp. Cobar-Coolabah; Cunningham & Milthorpe s.n. 2/8/73)		Vulnerable
	Boronia granitica	Granite boronia	Endangered
	Borya mirabilis	Grampians pincushion-lily	Endangered

Type/category	Scientific name	Common name	Current status
	Brachyscome muelleri		Endangered
	Calonema wanosa		Vulnerable
	Cynanchum elegans	White-flowered wax plant	Endangered
	Drakaea concolor	Kneeling hammer-orchid	Vulnerable
	Drakonorchis drakeoides	Hinged dragon orchid	Endangered
	Eremophila pinnatifida	Pinnate-leaf eremophila	Endangered
	Eriocaulon carsonii	Salt pipewort, button grass	Endangered
	Eucalyptus crucis subsp praecipua	Paynes find mallee	Endangered
	Grevillea beadleana	Beadle's grevillea	Endangered
	Grevillea iaspicula	Wee Jasper grevillea	Endangered
Plants (continued)	*Hakea maconochieana*		Vulnerable
	Homoranthus prolixus		Vulnerable
	Irenepharsus trypherus	Delicate cress, Illawarra Irene	Endangered
	Lachnagrostis limitanea	Spalding blown grass	Endangered
	Leionema ralstonii		Vulnerable
	Leucopogon confertus		Endangered
	Micromyrtus grandis		Endangered
	Pterostylis cucullata	Leafy greenhood	Vulnerable
	Pterostylis xerophila	Desert greenhood	Vulnerable

Type/category	Scientific name	Common name	Current status
	Pultenaea sp. Genowlan Point	Genowlan Point pultenaea	Critically endangered
	Sarcochilus hartmannii	Waxy sarcochilus, blue knob orchid	Vulnerable
	Senecio megaglossus	Superb groundsel	Vulnerable
	Stachystemon nematophorus	Three-flowered stachystemon	Vulnerable
	Swainsona murrayana	Slender Darling-pea, slender swainson, Murray swainson-pea	Vulnerable
	Westringia crassifolia	Whipstick westringia	Endangered
	Westringia davidii		Vulnerable
	Xerothamnella parvifolia		Vulnerable
	Zieria adenophora	Araluen zieria	Endangered
	Zieria buxijugum		Endangered
	Zieria floydii		Endangered
	Zieria parrisiae		Endangered
Unlisted species or taxa that could be adversely affected			
Plants	*Triodia bromoides*		

Glossary

Critically endangered	Under the EPBC Act, a native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
Endangered	Under the EPBC Act, a native species is eligible to be included in the endangered category at a particular time if, at that time, (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
Fecundity	Potential rate at which an organism reproduces.
Feral	An introduced animal, formerly in domestication, with an established self-supporting population in the wild.
Genotyping	The process of determining the genotype (i.e. the genetic makeup) of an individual with a biological assay.
Invasive species	A species occurring as a result of human activities beyond its accepted normal distribution and which threatens valued environmental, agricultural or personal resources by the damage it causes (Beeton et al. 2006).
Judas goat	The Judas goat method involves releasing a radio-collared goat into an area known to contain feral goats. Being social animals, the Judas goat will join any feral goats in the area. The goat can be relocated by means of directional radio-receiving equipment and hence the feral goat herd can be located and shot. The Judas goat can be allowed to escape and the process repeated until feral goats are no longer encountered. Hence, by using their sociability against them, goats can be eradicated.
Key threatening process	Under the EPBC Act, a process that threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.
Performance indicator	A criterion or measure that provides information on the extent to which a policy, program or initiative is achieving its outcomes.

Pest animal or species	Any non-human species of animal that causes trouble locally or over a wide area, to one or more persons, either by being a health hazard, a general nuisance, or by causing damage to agriculture, wild ecosystems or natural resources.
Threat abatement plan	Under the EPBC Act, a plan providing for the research, management, and any other actions necessary to reduce the impact of a listed key threatening process on affected species and ecological communities.
Threatened species	A species under the EPBC Act listed as critically endangered, endangered, vulnerable or conservation dependent.
Unmanaged goats	Goats that are free-living and not subject to livestock husbandry, but may be 'owned' in the sense that access for harvesting or control is determined by the owner or occupier of the land. This is in contrast to 'managed' goats, which are those held under some combination of animal husbandry methods (such as being owned, identified, restrained, managed for population structure and density, and receive welfare). Some goats, however, have one or more of the characteristics of managed goats, but in all other respects are indistinguishable from unmanaged animals with no husbandry.
Vulnerable	Under the EPBC Act, a native species is eligible to be included in the vulnerable category at a particular time if, at that time, (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria.

Acronyms and abbreviations

BRS	Bureau of Rural Sciences
DEWHA	Australian Government Department of the Environment, Water, Heritage and the Arts
EPBC Act	the Commonwealth Environment Protection and Biodiversity Conservation Act 1999
TAP	threat abatement plan

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Australian Government
Department of the Environment and Energy

Threat Abatement Plan

for

predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*) (2017)

Cover photo: A mob of 89 feral pigs (some out of frame) on the Wildman River floodplain, Northern Territory, 2013. Photographer: B. Salau.

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INTRODUCTION

In 2001 the Australian Government listed **'Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*)'** as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

This listing initiated the development of the *'Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs (Sus scrofa) (2005)'* which was made in 2005 and reviewed in 2011. This revised plan provides a national framework for feral pig management, research and education. It also aims to capture scientific research and other developments that have occurred since the first threat abatement plan was made, and capture changing priorities for feral pig management.

While this threat abatement plan aims primarily to abate the threat to key environmental assets (threatened species and ecological communities listed under the EPBC Act and other matters of national environmental significance), it also recognises that feral pigs have wider environmental impacts as well as social, cultural and economic impacts.

This document should be read in conjunction with the Background document, which provides information about feral pigs, their impacts on the environment, their economic impacts, their economic and social values, and their current management.

1. Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*) (2017)

1.1. Description of the process and its impacts

Feral pigs are found in all states and territories of Australia, particularly in association with wetlands and river systems. An estimate of the size of the nation's feral pig population is difficult as numbers fluctuate widely in response to wet and dry periods, and availability of food and water. In warmer areas of Australia, feral pigs' poor heat tolerance restricts their distribution to the vicinity of watercourses and floodplains. This factor is less critical in the forested parts of eastern and south-western Australia where they are more widespread.

Ecological parameters affected by feral pigs include plant species composition and succession, nutrient and water cycles, and water quality. Impacts can be direct, such as through predation and digging, or indirect, through long-term changes in species composition. Impacts may be seasonally influenced, and vary across Australia with different habitats.

Feral pigs are opportunistic omnivores and will consume animal material including small mammals, birds, reptiles, frogs, crayfish, eggs, and carrion; earthworms and other invertebrates; underground fungi; and all parts of plants including the fruit, seeds, roots, tubers, bulbs and foliage. Feral pigs vary their food consumption to match seasonal changes in food availability and quality. They have a poor capacity to digest cellulose and relatively high protein requirements, therefore regularly supplement their diet with carrion and animal prey.

Habitat changes due to feral pigs include: destruction of plants, sometimes threatening the survival of specific plant species through reduced or failed recruitment of new plants; changing the composition of plant communities; alteration of soil structure through digging and rooting; increased invasion and spread of weeds through spreading seeds via faeces or in fur, or creating suitable habitat through soil enrichment with urine and faeces or ground disturbance; reduced water quality through disturbance of riparian zones and bodily wastes; and creation of

habitat suitable for plant disease vectors.

Feral pigs provide reservoirs for endemic animal diseases such as leptospirosis and brucellosis, which can cause birth defects, abortions and infertility in mammals. They may be vectors of exotic diseases such as foot-and-mouth disease, should they ever reach Australia. They can spread exotic plant pathogens such as *Phytophthora cinnamomi,* which causes plant dieback, through soil movement on their feet and fur, and by passing viable spores in their faeces.

For further detail, consult the Background document.

1.2. Managing the threat

It is not possible to eradicate feral pigs from Australia with current resources and techniques, and it is unlikely to be possible in the near future, as they are so widely established. As such, the focus of feral pig management must be on abatement of the impacts unless they are in small isolated areas (e.g. islands) where eradication may be feasible. There are a range of control methods available for feral pigs including trapping, aerial and ground shooting, poisoning, and fencing. Other techniques, including the use of tracking dogs to detect and flush out (but not attack) feral pigs[1], coordination with commercial harvesters and habitat manipulation (e.g. reducing watering points and/or crop waste for feral pigs to utilise), can contribute to the control methods used.

Feral pigs are mobile animals that have a very high rate of reproduction, particularly in good conditions. Managing environmental damage due to feral pigs requires an integrated and coordinated approach, often across a variety of land uses including national parks, reserves and agricultural lands.

Best-practice management of feral pigs must involve threat abatement not only for identified threatened species but also for other native species that may be affected by feral pig predation, habitat degradation, competition and disease transmission.

1.3 Threat abatement plans

This threat abatement plan sets out a suggested series of actions and strategies to manage the impacts of feral pigs across the nation, as well as providing a suggested timeline and prioritisation for activities. The actions are informed by the review of the previous threat abatement plan, new scientific research and developments, and input from feral pig experts.

1.4. Implementation

Under the EPBC Act, the Australian Government develops threat abatement plans and facilitates their implementation. The EPBC Act requires the Australian Government to implement threat abatement plans to the extent to which they apply in areas under Australian Government control and responsibility. Where a threat abatement plan applies outside Australian Government areas in states or territories, the Australian Government must seek the cooperation of the affected jurisdictions, with a view to jointly implementing the threat abatement plan.

The Australian Government Department of the Environment and Energy will assist other Australian Government agencies and state, territory and local governments, national and regional industry and community groups towards implementing this threat abatement plan. By providing a national framework, this threat abatement plan will assist in the coordination and

[1] Regulations on the use of dogs in hunting vary in each jurisdiction. Nationally agreed Standard Operating Procedures and Codes of Conduct regarding feral pig control and some state legislation (e.g. Victoria) dictate that use of dogs must be restricted to detecting and flushing out feral pigs, and that dogs **must not** be encouraged nor allowed to attack feral pigs.

enhancement of relevant strategies and activities across affected jurisdictions.

This threat abatement plan provides a strategic framework for the management of feral pigs in Australia, namely to:

- manage feral pigs within policy, legislative and planning frameworks
- reduce the spread of feral pigs to new areas within Australia, including via illegal releases
- manage feral pigs based on the protection of values and assets
- build Australia's capacity to address feral pig problems and improve feral pig management
- raise awareness and motivation among Australians to strengthen their commitment to act on feral pig problems, and
- monitor and evaluate the progress of Australia's feral pig management effort.

The successful implementation of this threat abatement plan will depend on a high level of cooperation between landholders, community groups, local government, state and territory conservation and pest management agencies, and the Australian Government and its relevant agencies. Success will depend on all participants assessing feral pig impacts and allocating adequate resources through available funding channels, programs, etc. to achieve effective on-ground control of feral pigs at critical sites, improve the effectiveness and humaneness of control programs, and measure and assess outcomes. Various programs in natural resource management, at national, state and regional levels, can make significant contributions to implementing the plan.

This threat abatement plan acknowledges the principles for effective pest animal management enshrined in the Australian Pest Animal Strategy (http://www.environment.gov.au/biodiversity/invasive-species/publications/australian-pest-animal-strategy).

2. Objectives and actions

The overarching goals of this threat abatement plan are to **prevent further species and ecological communities from becoming threatened or extinct due to predation, habitat degradation, competition and disease transmission by feral pigs, and to improve protection for EPBC-listed species and ecological communities currently threatened by feral pigs**. A reduction in the total number of EPBC-listed species and ecological communities threatened by feral pigs is also desirable but may be unlikely due to the extremely high and ongoing level of pig control this would require.

These goals can be achieved by improving our scientific understanding of the threatening process that feral pigs represent and its effects on native species and ecological communities, and improving management and control of feral pigs. To achieve these goals, the threat abatement plan has six objectives that were developed in consultation with experts in relevant jurisdictions. These objectives are to:

1. Prioritise key species, ecological communities, ecosystems and locations across Australia for strategic feral pig management

2. Encourage the integration of feral pig management into land management activities at regional, state and territory, and national levels

3. Encourage further scientific research into feral pig impacts on nationally threatened species and ecological communities, and feral pig ecology and control

4. Record and monitor feral pig control programs, so their effectiveness can be evaluated

5. Build capacity for feral pig management and raise feral pig awareness amongst landholders and land managers, and

6. Improve public awareness about feral pigs and the environmental damage and problems they cause, and the need for the feral pig control.

Each objective is accompanied by a set of actions which, if implemented, will help to achieve the goals of the threat abatement plan. Performance indicators (outcomes and outputs) have been established for each objective. Reports on progress against the objectives may be sought by the Australian Government Department of the Environment and Energy in years 4–5 for the purpose of assessing the effectiveness of the threat abatement plan.

Objective 1: *Prioritise key species, ecological communities, ecosystems and locations across Australia for strategic feral pig management.*

The key purpose of this threat abatement plan is to address the key threatening process—predation, habitat degradation, competition and disease transmission by feral pigs. It is therefore necessary to identify the important ecosystems, habitats and species that may need protecting through research findings, qualitative assessments and stakeholder/landholder discussions.

From the perspective of the Australian Government Department of the Environment and Energy, the key species and ecosystems are those listed as threatened under the EPBC Act, for which feral pigs are a key threatening process. A list of EPBC-listed species and ecological communities negatively affected by feral pigs is at Appendix B.

The Department of the Environment and Energy has also attempted to provide some recognition in this threat abatement plan for species and ecosystems that are currently unlisted and do not trigger specific attention under the EPBC Act, but are at risk of becoming listed under the EPBC Act if feral pig impacts continue. Similarly, species, ecosystems and locations considered important for other reasons, or by other stakeholders (e.g. state-listed, culturally important, iconic) should also be taken into consideration when planning feral pig programs.

Identifying the locations of key species, ecological communities, and ecosystems under significant threat by feral pigs is an important foundation for Objective 1. Through knowing the key areas requiring feral pig control and protection, land managers can more effectively integrate and prioritise feral pig management into their management activities and, where necessary, seek long-term funding. It will also provide these land managers with information about what feral pig control actions they can undertake and how to measure the effectiveness of these control actions.

Action	Priority/ Timeframe	Outcome	Output	Key Actioners
Action 1.1: Identify key species, ecological communities, ecosystems and locations for priority protection. Note EPBC-listed threatened species and ecological communities. Factor in other sites/species/ecosystems where appropriate (e.g. cultural, iconic).	High priority. Years 1–2 with ongoing refinement where necessary.	Key species, ecological communities, ecosystems and locations prioritised for protection and management. Linkages to recovery plans or pest management strategies where they exist or are made.	Spatially explicit report that identifies priority areas for pig control.	To be undertaken by the Australian Government and other land managers in consultation with experts. *This action will require careful consultation to ensure all priority factors are considered, and communication of priority species, ecological communities, ecosystems and locations to affected land managers.*
Action 1.2: Implement feral pig control in priority areas, combining national priorities and local	Medium priority.	Small areas of high / special environmental value in need of	Feral pig damage to small areas of high / significant	Regional groups and land managers. *This action will require*

Action	Priority/ Timeframe	Outcome	Output	Key Actioners
knowledge into on-ground action.	Years 1–2.	feral pig management better identified.	environmental value measurably reduced.	*the detailed understanding of habitats within regions and their relative importance across the region, which requires on-ground knowledge.*

Objective 2: *Encourage the integration of feral pig management into land management activities at regional, state and territory, and national levels.*

Feral pigs are a serious pest and cause extensive damage to natural habitats as well as to agricultural industries. Feral pig management should be regarded as a standard component of land management. In encouraging the integration of feral pig management into ongoing practices by land managers, the intent is to increase recognition that the problem requires long-term mitigation rather than occasional periods of action. Long-term suppression of feral pig numbers will assist in reducing the pressure on threatened species and ecological communities affected by feral pigs and increase the resilience of these species and communities.

Feral pigs are highly mobile across the landscape in response to changing conditions, so cooperation between land managers in broad scale management programs will benefit threatened species and ecological communities as well as limiting the damage to primary production impacted by feral pigs, including cropping and grazing enterprises. A well designed control program will reduce the ability of feral pig populations to reach high densities during favourable conditions. Integrating a feral pig management program into the standard land management activities of a property may allow managers to seek efficiencies through combining activities. Some examples are provided below. All levels of government; regional groups such as Natural Resource Management groups, Landcare groups; state land service agencies (e.g. Local Land Services (NSW)); and local groups such as "Friends of..." groups are encouraged to integrate feral pig management into land management activities.

Action	Priority/ Timeframe	Outcome	Output	Key Actioners
Action 2.1: Encourage the integration of feral pig management into land management activities at all levels of government, and regional groups. For more consistent and effective feral pig management across Australia, all government departments and agencies with land management responsibilities should aim to integrate feral pig management into their land management activities (e.g. weed control, threatened species surveying/recovery work, fuel reduction, etc.) and planning. Similarly, regional groups such as Natural Resource Management groups, Landcare groups and Local Land Services should aim to integrate feral pig management into their land management activities.	High priority. Years 1–5. (ongoing)	More consistent and effective feral pig management occurs across Australia at all levels of government, and in regional groups. Inclusion of actions to mitigate the impacts of feral pigs on key species, ecological communities and ecosystems into land or property plans, for areas where feral pigs have been identified as a problem.	Reduction in environmental damage by feral pigs. AND/OR A reduction in feral pig populations as a proxy for reduced environment damage. Increased participation of groups and individuals in feral pig management.	Land managers.

Objective 3: *Encourage further scientific research into feral pig impacts on nationally threatened species and ecological communities, and feral pig ecology and control.*

Further experimental research is needed to quantify the environmental impacts of feral pigs, particularly their impacts on threatened species and ecological communities. Specifically:

- the relationship between the number of pigs and the level of impact (within specific areas and ecosystems) needs to be quantified where possible, to help land managers decide how much control effort is needed
- the impacts of feral pigs in environments where they are abundant including temperate inland river/wetland complexes. It is noted some research has been conducted already in the Wet Tropics and sub-alpine peat bogs
- understanding the landscape factors, and interactions between these landscape factors, that drive feral pigs' ecology and their interactions/impacts with the environment. This includes understanding how feral pigs use a variety of habitats or microhabitats in a landscape, and research into their transient movements following wet seasons or inland water flows (e.g. Channel Country), and
- the development of indicators for how and when to undertake feral pig control work for a particular region or ecosystem. These indicators need to include triggers related to space and time, and may be developed as part of the research described above.

Importantly, further research should be undertaken into the effectiveness of feral pig control methods. The results of this research need to be communicated to land managers so that they can adopt these methods and achieve better outcomes for threatened species and ecological communities. Collaborative applied research projects may allow specific knowledge gaps to be targeted and filled, and bring additional benefits of knowledge exchange and connection.

Understanding and quantifying the environmental impacts of feral pigs on threatened species and ecological communities works towards the goals of the threat abatement plan, by providing a better understanding of how feral pigs can be controlled, or how other measures can be taken to lessen the impact of feral pigs. Understanding the potential opportunities for range expansion and population growth and therefore impacts across all areas of Australia, particularly south-eastern Australia, will also be important.

Action	Priority/ Timeframe	Outcome	Output	Key Actioners
Action 3.1: Research into feral pigs impacts on nationally threatened, and near-threatened, species and ecological communities. Identified recovery actions should be included in research proposals related to feral pigs.	High priority. Years 1–5.	Increase in feral pig research activity. Greater understanding of feral pig impacts on nationally threatened, and near-threatened, species and ecological communities. More informed and effective feral pig management.	Research papers and reports focused on understanding feral pig impacts on nationally threatened, and near-threatened, species and ecological communities published. Recovery plans, as they are updated, reflect the improved knowledge of feral pig management needs.	Commonwealth, state and territory agencies funding or commissioning research. Researchers. *As this type of research will require field studies, the involvement of local land managers and groups may provide valuable assistance.*

Action	Priority/ Timeframe	Outcome	Output	Key Actioners
Action 3.2: Research into feral pig population dynamics and ecology. A greater understanding of feral pig population dynamics and ecology will aid in feral pig management.	Medium priority. Years 1–5.	Improved knowledge leading to more informed and effective feral pig management.	Research papers and reports focused on understanding feral pig population dynamics and ecology published. Research translates into improved quality and currency of information/ guidance for land managers undertaking feral pig control programs.	Commonwealth, state and territory agencies funding or commissioning research. Researchers. *As this type of research will require field studies, the involvement of local land managers and groups may provide valuable assistance.*
Action 3.3: Research into spatial and temporal use of landscapes by feral pigs. A greater understanding of feral pigs' use of the landscape and how it varies spatially and over time will aid feral pig management.	Medium priority. Years 1–5.	Improved knowledge leading to more informed and effective feral pig management. Improved knowledge to target appropriate timing for feral pig management or placement of control techniques.	Research papers and reports focused on understanding feral pig spatial and temporal landscape use published. Research translates into improved quality and currency of information/ guidance for land managers undertaking feral pig control programs.	Commonwealth, state and territory agencies funding or commissioning research. Researchers. *As this type of research will require field studies, the involvement of local land managers and groups may provide valuable assistance.*
Action 3.4: Research into the effectiveness of feral pig control methods.	Medium priority. Years 1–5.	Improved knowledge leading to managers effectively applying control methods in a more efficient manner.	Research papers and reports focused on the effectiveness of control methods published. Research translated into easily accessible information for managers to adopt in their control programs.	Commonwealth, state and territory agencies funding or commissioning research. Researchers and land managers. *This research will require field studies, and ideally be done in conjunction with local land managers and groups undertaking control programs.*

Objective 4: *Record and monitor feral pig control programs, so their effectiveness can be evaluated.*

Feral pig control programs need to be recorded and monitored, where possible, so that their effectiveness can be evaluated. National recording of this monitoring data should be encouraged, as it allows state and territory agencies and other stakeholders/land managers across Australia to find out where and when feral pig control programs are carried out, how effective they are, and increases opportunities for collaborative control efforts. An existing platform that fulfils many of these functions is FeralPigScan (www.feralscan.org.au/feralpigscan/). FeralPigScan allows recording and mapping of feral pigs sightings and damage, as well as feral pig control activities occurring in local community areas. The data recorded is available to the community to help decide where to undertake control, and coordinate with neighbours.

Action	Priority/ timeframe	Outcome	Output	Key Actioners
Action 4.1: Encourage monitoring to enable the evaluation of the effectiveness of feral pig control. Monitoring of appropriately chosen sites will allow the effectiveness of feral pig control to be evaluated, and will allow land managers to change feral pig control actions as necessary. In particular, monitoring of threatened species/ecological communities being impacted by feral pigs can determine whether changes in feral pig abundance caused by feral pig control are resulting in a positive response in those threatened species/ecological communities. Sharing information on effectiveness of control actions will allow other land managers to learn from it.	High priority. Years 1–5.	Feral pig control actions include site monitoring and effectiveness. Increased use of FeralPigScan to improve this platform's information base and usefulness.	Information to refine feral pig control actions.	Land managers undertaking control programs or contractors working for land managers.
Action 4.2: Develop further effective monitoring techniques.	High priority.	Effective monitoring techniques that can be used by non-specialist land managers.	Information to judge the effectiveness of feral pig control techniques.	State and territory agencies. Research institutions.

Action	Priority/ timeframe	Outcome	Output	Key Actioners
Action 4.3: Encourage the use of the existing FeralPigScan platform for centralised recording platform of feral pig control actions and any monitoring/recording of their effectiveness. *Issues of data standards, data security and data access may need to be considered.*	Medium priority. Years 1–5.	Increased use of FeralPigScan to improve this platform's information base and usefulness.	Data on where and how feral pigs are controlled available for regional, state/territory and national planning and prioritisation.	Australian, state and territory governments to determine feasibility. *If this is implemented land managers will need to provide information.*

Objective 5: Build capacity for feral pig management and raise feral pig awareness amongst landholders and land managers.

Building capacity amongst landholders and land managers will enable them to undertake feral pig management more effectively and confidently. Raising awareness of feral pigs and their environmental impacts amongst landholders and managers will also increase their support for, and participation in, management and control measures. Measures for achieving this will include effectively communicating the outcomes of research.

Building capacity in feral pig management links to the goals of the threat abatement plan by providing support for landholders protecting threatened species and ecological communities.

There are many diverse views within the broader community, including Indigenous communities, on the value of feral pigs, and these may also vary within groups over time or location (See Background document for detail). Further understanding on how these values may be respected while also undertaking appropriate feral pig management is needed.

It is also important to recognise the significant expertise some land managers, including Indigenous land managers, have from many years of on-the-ground experience managing feral pigs, and creating opportunities for the sharing, exchange and capturing of this knowledge.

Action	Priority/ timeframe	Outcome	Output	Key Actioners
Action 5.1: Increase delivery of training courses and/or extension programs to build feral pig management skills amongst landholders and land managers Training courses / extension programs will acquaint participants with: • current humane feral pig management products and techniques • relevant legislation, including animal welfare legislation • codes of practice and standard operating	High priority. Years 1–5.	Increased capability to manage feral pigs amongst landholders and land managers. More feral pig management undertaken by landholders and land managers.	Formal vocational training courses (e.g. Certificate III in Vertebrate Pest Management) available in all states and territories. Where records are available, the ongoing delivery of vertebrate pest management information or training at agricultural and town shows, field days and public meetings. Ongoing access of feral pig training material available on the PestSmart Connect website (http://www.pestsmart.org.au/) (developed by the Invasive Animals Cooperative Research Centre).	TAFEs, universities, organisations delivering agricultural and natural resource management advice (e.g. Natural Resource Management, Local Land Services, state and territory government departments). *Delivery of training takes place formally through courses or workshops and informally through agricultural and town shows, field days and public meetings.*

Action	Priority/ timeframe	Outcome	Output	Key Actioners
procedures • the value of monitoring, and basic techniques for monitoring.				
Action 5.2: Increase understanding of social impediments to feral pig control.	Medium priority. Years 1–5.	Feral pig management programs tailored to take account of social factors, including Indigenous social factors, while protecting threatened species/ ecological communities. Create opportunities for discussion and exchange of ideas and experience regarding feral pig control.	Guidance available to land managers undertaking control programs.	Researchers in association with TAFEs, universities, organisations delivering agricultural and natural resource management advice.

Objective 6: *Improve public awareness about feral pigs and the environmental damage and problems they cause.*

Most Australians now live in urban or semi-urban areas. They generally do not see feral pigs and are rarely confronted by the damage and problems they cause. Consequently, most Australians lack awareness of the feral pig problem, and may have no concept of the need for feral pig control. It is important to improve public awareness about feral pigs and the environmental damage and problems they cause, and the need for effective feral pig control programs, to ensure there is lasting public support for management and research. This includes emphasising the limited effectiveness of uncoordinated recreational hunting on long-term, broad-scale feral pig control.

Feral pigs also impact on primary production through predation on livestock, damage to crops and through harbouring diseases that may affect livestock. These diseases may also affect humans and secondary impacts from feral pigs, such as water quality in supply catchments, can also cause human health issues. While these are not the focus of this threat abatement plan, educating people about these issues can lend support to feral pig control for biodiversity outcomes.

Indigenous communities hold a range of values for feral pigs that are explored in some detail in the Background document.

Feral pigs can be highly mobile, taking advantage of changes in environmental conditions or changes in land management. The deliberate movement of feral pigs by people may also be a contributing factor to their dispersal and abundance. Members of the public should be encouraged to report new populations or significant changes in abundances of feral pigs to assist with control actions, and to come forth with evidence that may assist agencies take action against individuals who deliberately take feral pigs captive and release them elsewhere.

Action	Priority/ timeframe	Outcome	Output	Key Actioners
Action 6.1: Develop and deliver a public education program about feral pigs and the environmental damage and problems they cause. Raising public awareness of feral pigs is necessary. Where opportunities arise, such as in conjunction with feral pig management programs or as a component of a broader program raising awareness of invasive/feral animals generally, a public education campaign can be run.	Low priority. Years 1–5.	Greater public awareness of the environmental damage feral pigs cause, and the problems feral pigs cause to both the environment and primary producers. Public support is forthcoming for funding feral pig control programs.	Media monitoring shows an increase in stories/articles or awareness of the feral pig problem. AND/OR Public surveys on the environment indicate an awareness of the feral pig problem.	Australian, state and territory biosecurity agencies. *Specific control programs should deliver education in local areas as appropriate.*

Action	Priority/ timeframe	Outcome	Output	Key Actioners
Action 6.2: Ensure deterrents are in place to discourage the translocation of feral pigs, and include this information in community education programs	Medium priority. Years 1–5	Greater public awareness of biosecurity regulations related to feral pigs. Public support is forthcoming to minimise the dispersal and abundance of feral pigs	Public surveys on the environment indicate an awareness of regulation related to feral pigs.	Relevant state and territory authorities.

3. Duration, cost and evaluation of the plan

This threat abatement plan provides guidance to identify priority areas and undertake actions targeted at these areas. Investment in many of the actions listed in this threat abatement plan will be determined by the level of resources that stakeholders commit to managing the problem.

Budgetary and other constraints may affect the achievement of the objectives of this threat abatement plan and, as knowledge changes, proposed actions may be modified over the life of this threat abatement plan. Australian Government funds may be available to implement key national environmental priorities, such as relevant actions listed in this threat abatement plan, and actions identified in regional natural resource management plans that are consistent with this threat abatement plan. Achievement of the overarching goal of this threat abatement plan will require ongoing management beyond the life of the threat abatement plan. Ongoing support by all partners is therefore essential.

3.1 Duration

This plan reflects the fact that the threat abatement process will be ongoing, as there is no possibility of nationally eradicating feral pigs in the life of this plan. The plan lays out measures that should be taken in the next five years to reduce the impact from the key threatening process of predation, habitat degradation, competition and disease transmission by feral pigs. Within the life of this threat abatement plan the focus is on suppressing and managing the impacts of feral pigs in targeted areas where they pose the greatest threat to biodiversity.

Threat abatement plans have a statutory review point at intervals of not longer than five years. Depending on the degree of implementation and the success of that implementation, some or many of the objectives and actions in this plan may be varied following this review.

3.2 Investment in the plan

Investment in many of the threat abatement plan actions will be determined by the level of resources that stakeholders commit to management of the problem. The Commonwealth is committed, via the EPBC Act, to implement the threat abatement plan to the extent to which it applies in Commonwealth areas. However, it should be noted that the Australian Government is unable to provide funding to cover all actions in this threat abatement plan across all of Australia and requires financial and implementation support from stakeholders. Partnerships amongst and between governments, non-government organisations, community groups and individuals will be key to successfully delivering significant reductions in the threats posed by feral pigs.

3.3 Costings

Outlined below are some estimates of costs of implementation of the actions within the plan. They have been obtained from multiple agencies and individuals actively engaged in feral pig control; in some instances more than one costing has been provided for an activity. Costings have been placed in this section instead of against each objective because it is difficult to fully cost the implementation of each action because of unknown variables. In particular, research or field project costs are going to be highly variable dependent on the subject and location. A more remote location, or one with difficult access, will cost more than an accessible site. Other actions are contingent on particular prior actions (e.g. identification of high priority sites) and cannot be accurately costed until the prior action is undertaken. What is presented here are estimates of different elements to actions within the plan to provide a guide to governments, researchers, land managers, island owners, community and others when considering what actions they may be able to implement.

Anyone looking to implement an action is strongly recommended to undertake their own budget exercise for their particular circumstances and the outcomes sought.

Action	Cost anticipated or known at time of TAP development for action times	Comments
Exclusion fencing	Fencing (total cost) $7,000–14,000 per kilometre. Components: Fencing materials $2,600 per kilometre Fencing labour $45 per hour	Can be double in hilly country
Trapping	Trap costs $650–800 each; comprising: Trapping materials for 1 trap $200–500 Labour – construction for 1 trap ranges from $25–$45 per hour for one day per trap. Maintenance labour with vehicle is $100,000 per year. An extra person adds $70,000 per year. Labour – checking traps $45 per hour, full day to check traps. Vehicle use $1.20 per kilometre and may average 150 km per day. Materials – bait (molasses/ apples/grain) $10 per kilogram. Also need to include ammunition/firearm costs plus training requirements for use of corporate firearms.	Depends on trap type – these estimates are provided for a weldmesh style figure 6 trap.
Aerial shooting	Helicopter $1100–1200 per hour of flight Labour $75 per hour of flight Ammunition $100–150 per hour of flight	
Poisoning with 1080 (meat or grain baits)	Grain + 1080 at 0.016 litres (16 mls) per kilogram, $250–300 per 100 kilograms Meat $1.80 per bait (2.4 mls injected 1080) Grain is $12/25kg, need to pre-feed for 1 month. Baiting programs can cost as little as $1,000–2,000 for the materials.	
Poisoning with sodium nitrite (estimated; not released for use yet)	Estimated $60 for quantity sufficient to kill up to 20 pigs	

Action	Cost anticipated or known at time of TAP development for action times	Comments
Research projects, including development of new control tools and models	$250,000 annually per researcher.	
Social research into barriers for pig control	$200,000 including community engagement.	Estimated $200,000 over whole of TAP (nationally; 5 years).
Prioritisation of pig control areas	$100,000 for initial regional reviews of areas per state/territory.	Estimated $800,000 plus additional funding for finer scale prioritisation over whole of TAP (nationally; 5 years).
Development of coordinated reporting mechanisms	$50,000 per state/territory.	Estimated $300,000 over whole of TAP (nationally; 5 years).
Development of management plans	$10,000 for each regional plan.	Estimated $200,000 for 20 regions.
Community education	$200,000 per state/territory for general promotion per year. This amount may decline as material can be reused and education levels rise.	Estimated $1.2 million per state/territory over 5 years.
Training	$10,000 to $100,000 to develop different materials and programs. $2,000 to $100,000 for delivery.	Estimated $250,000 over whole of TAP (nationally; 5 years). Estimated over $300,000 over whole of TAP (nationally; 5 years).

This threat abatement plan provides a framework for undertaking targeted priority actions. Budgetary and other constraints may affect the achievement of the objectives of this plan, and as knowledge changes, proposed actions may need to be modified over the life of the plan. Australian Government funds may be available to implement key national environmental priorities, such as relevant actions listed in this plan and actions identified in regional natural resource management plans.

3.3 Evaluating implementation of the plan

In many situations it may be difficult to assess directly the effectiveness of the plan in abating the impacts of feral pigs on Australia's biodiversity. However, performance indicators have been provided against each of the objectives to provide an indication of the level of threat abatement that has been achieved.

Measurements in the improvement of threatened species populations or conditions can be monitored, particularly where the primary threat is feral pig predation (e.g. percentage of marine turtle nests not preyed upon and hatching successfully). However, in many situations,

feral pig management is only an element of a complete recovery plan, so being able to accurately assess impact of feral pig control may be difficult. Individual feral pig control programs with comprehensive monitoring may be able to record recoveries in threatened species populations.

GLOSSARY

EPBC Act	The *Environment Protection and Biodiversity Conservation Act 1999*, the Australian Government's environment legislation.
Key threatening process	A threatening process listed under the EPBC Act that meets any of the following criteria: • could cause a native species or an ecological community to become eligible for listing in any category, other than conservation dependent • could cause a listed threatened species or a listed threatened ecological community to become eligible to be listed in another category representing a higher degree of endangerment • adversely affects two or more listed threatened species (other than conservation dependent species) or two or more listed threatened ecological communities.
Threatened ecological community	An ecological community listed under the EPBC Act as being critically endangered, endangered or vulnerable.
Threatened species	A species listed under the EPBC Act as being critically endangered, endangered, vulnerable or conservation dependent.
Near-threatened species	A species currently not listed as threatened under the EPBC Act, but being impacted by threats in such a way that they could become eligible for listing as threatened in the near future. Note this is a purely descriptive term used for purposes of this document and is not a legal term or category used in the EPBC Act.

APPENDIX A: COMMONWEALTH LEGISLATION RELEVANT TO THREAT ABATEMENT PLANS

The following extracts from the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Environment Protection and Biodiversity Conservation Regulations 2000, which are relevant to the making of threat abatement plans, are provided for information only, and are not legal documents.

Content of threat abatement plans—*Environment Protection and Biodiversity Conservation Act 1999*

Section 271 Content of threat abatement plans

(1) A threat abatement plan must provide for the research, management and other actions necessary to reduce the key threatening process concerned to an acceptable level in order to maximise the chances of the long-term survival in nature of native species and ecological communities affected by the process.

(2) In particular, a threat abatement plan must:

(a) state the objectives to be achieved; and

(b) state criteria against which achievement of the objectives is to be measured; and

(c) specify the actions needed to achieve the objectives; and

(g) meet prescribed criteria (if any) and contain provisions of a prescribed kind (if any).

(3) In making a threat abatement plan, regard must be had to:

(a) the objects of this Act; and

(b) the most efficient and effective use of the resources that are allocated for the conservation of species and ecological communities; and

(c) minimising any significant adverse social and economic impacts consistently with the principles of ecologically sustainable development; and

(d) meeting Australia's obligations under international agreements between Australia and one or more countries relevant to the species or ecological community threatened by the key threatening process that is the subject of the plan; and

(e) the role and interests of Indigenous people in the conservation of Australia's biodiversity.

(4) A threat abatement plan may:

(a) state the estimated duration and cost of the threat abatement process; and

(b) identify organisations or persons who will be involved in evaluating the performance of the threat abatement plan; and

(c) specify any major ecological matters (other than the species or communities threatened by the key threatening process that is the subject of the plan) that will be affected by the plan's implementation.

(5) Subsection (4) does not limit the matters that a threat abatement plan may include.

Section 274 Scientific Committee to advise on plans

(1) The Minister must obtain and consider the advice of the Scientific Committee on:

(a) the content of recovery and threat abatement plans; and

(b) the times within which, and the order in which, such plans should be made.

(2) In giving advice about a recovery plan, the Scientific Committee must take into account the following matters:

(a) the degree of threat to the survival in nature of the species or ecological community in question;

(b) the potential for the species or community to recover;

(c) the genetic distinctiveness of the species or community;

(d) the importance of the species or community to the ecosystem;

(e) the value to humanity of the species or community;

(f) the efficient and effective use of the resources allocated to the conservation of species and ecological communities.

(3) In giving advice about a threat abatement plan, the Scientific Committee must take into account the following matters:

(a) the degree of threat that the key threatening process in question poses to the survival in nature of species and ecological communities;

(b) the potential of species and ecological communities so threatened to recover;

(c) the efficient and effective use of the resources allocated to the conservation of species and ecological communities.

Section 279 Variation of plans by the Minister

(1) The Minister may, at any time, review a recovery plan or threat abatement plan that has been made or adopted under this Subdivision and consider whether a variation of it is necessary.

(2) Each plan must be reviewed by the Minister at intervals of not longer than 5 years.

(3) If the Minister considers that a variation of a plan is necessary, the Minister may, subject to subsections (4), (5), (6) and (7), vary the plan.

(4) The Minister must not vary a plan, unless the plan, as so varied, continues to meet the requirements of section 270 or 271, as the case requires.

(5) Before varying a plan, the Minister must obtain and consider advice from the Scientific Committee on the content of the variation.

(6) If the Minister has made a plan jointly with, or adopted a plan that has been made by, a State or self-governing Territory, or an agency of a State or self-governing Territory, the Minister must seek the cooperation of that State or Territory, or that agency, with a view to varying the plan.

(7) Sections 275, 276 and 278 apply to the variation of a plan in the same way that those sections apply to the making of a recovery plan or threat abatement plan.

Content of threat abatement plans—Environment Protection and Biodiversity Conservation Regulations 2000

Part 7 Species and communities

Regulation 7.12. Content of threat abatement plans.

For paragraph 271 (2) (g) of the Act, a threat abatement plan must state:

(a) any of the following that may be adversely affected by the key threatening process concerned:

(i) listed threatened species or listed threatened ecological communities;

(ii) areas of habitat listed in the register of critical habitat kept under section 207A of the Act;

(iii) any other native species or ecological community that is likely to become threatened if the process continues; and

(b) in what areas the actions specified in the plan most need to be taken for threat abatement.

APPENDIX B: EPBC-LISTED SPECIES AND ECOLOGICAL COMMUNITIES IMPACTED BY FERAL PIGS

The following species and ecological communities are listed as threatened under the EPBC Act. They have been extracted from the Department of the Environment and Energy's Species Profile and Threats (SPRAT) database after being identified as threatened or potentially threatened by feral pigs. The SPRAT database is compiled using data from multiple sources, including state and territory conservation agencies, research organisations and individual researchers.

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Amytornis barbatus barbatus (Grey Grasswren (Bulloo)	Endangered	Bird	Perceived	There are a number of factors which may contribute to habitat degradation including rooting (digging) by feral pigs.
Casuarius casuarius johnsonii (Southern Cassowary (Australian), Southern Cassowary)	Endangered	Bird	Known	Southern cassowary occurs along the eastern part of Cape York. Feral pigs degrade the bird's habitat by degrading water sources. Feral pigs probably compete with Southern Cassowaries for fallen fruit. Pig traps are also known to have resulted in the deaths of some cassowaries. Feral pigs wallowing and rooting around the edges of watercourses and swamps degrade habitat and affect water quality
Dasyornis brachypterus (Eastern Bristlebird)	Endangered	Bird	Known	Feral pigs damage habitat, particularly by uprooting Wild Sorghum.
Epthianura crocea macgregori (Yellow Chat (Dawson))	Critically Endangered	Bird	Perceived	Current habitat is being grazed by... feral pigs which may be causing long-term habitat degradation.

[2] The 'Grouping' field is not strictly taxonomic, and is designed to allow people to find plants and animals of interest under common names/labels rather than under taxonomic labels.

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Epthianura crocea tunneyi (Yellow Chat (Alligator Rivers))	Endangered	Bird	Known	Immediate threat ... is habitat damage by feral pigs.
Erythrura gouldiae (Gouldian Finch)	Endangered	Bird	Known	In the Northern Territory, habitat degradation by feral pigs can destroy or reduce wet season foraging habitat for these birds.
Geophaps smithii blaauwi (Partridge Pigeon (western))	Vulnerable	Bird	Perceived	Potential threats include grazing and trampling of habitat by feral animals particularly cattle (*Bos taurus*), donkeys (*Equus asinus*) and feral pigs (*Sus scrofa*).
Leipoa ocellata (Malleefowl)	Vulnerable	Bird	–	Added on advice of Parks Victoria in October 2015.
Malurus coronatus coronatus (Purple-crowned Fairy-wren (western))	Endangered	Bird	Known	Identified threats include grazing and trampling of habitat by cattle and feral herbivores, notably water buffalo (*Bubalus bubalis*), donkeys (*Equus aqinus*) and feral pigs (*Sus scrofa*).
Neochmia phaeton evangelinae (Crimson Finch (white-bellied))	Vulnerable	Bird	Known	Grazing mammals such as feral pigs and cattle can degrade riparian habitats during the dry season when they congregate around sources of fresh water and destroy the rank grasses by feeding upon and trampling them.
Pedionomus torquatus Plains Wanderer	Critically Endangered	Bird	–	Added on advice from Parks Victoria in October 2015.
Psephotus chrysopterygius (Golden-shouldered Parrot)	Endangered	Bird	Perceived	A shortage of food occurs annually in the early wet season and this can be made worse by intense cattle and feral pig grazing. Pigs and cattle can also destroy the termite mounds that the parrots breed in.
Turnix melanogaster (Black-breasted Button-quail)	Vulnerable	Bird	Known	Affected by grazing and other disturbances caused by cattle, horses and feral pigs; being ground-nesters, they are also affected by predation by cats, foxes and pigs.
Euploea alcathoe enastri (Gove Crow Butterfly)	Endangered	Butterfly	Perceived	Feral animals, particularly water buffalo *Bubalus bubalis* and feral pigs *Sus scrofa*, are on the Gove Peninsula. Such animals are known to damage monsoon rainforest habitat, and may also damage the groundwater forest which is the habitat where the Gove Crow Butterfly occurs.
Paralucia spinifera (Bathurst Copper Butterfly, Purple Copper Butterfly, Bathurst Copper, Bathurst Copper Wing, Bathurst-Lithgow Copper, Purple Copper)	Vulnerable	Butterfly	Known	Feral pigs have been identified as a threat to Native Blackthorn (*Bursaria spinosa subsp. Lasiophylla*), a tall native shrub that this species only occurs in the presence of.

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Engaeus martigener (Furneaux Burrowing Crayfish)	Endangered	Crayfish (Burrowing)	Perceived	Feral pigs have previously been identified as a potential risk to the species through the pigs' digging. While burrow depth would again appear to protect crayfish from the direct effects of such disturbance, this is an issue that needs to be addressed.
Engaewa reducta (Dunsborough Burrowing Crayfish)	Critically Endangered	Crayfish (Burrowing)	Perceived	Main potential threats include feral pigs.
Engaewa walpolea (Walpole Burrowing Crayfish)	Endangered	Crayfish (Burrowing)	–	Main potential threats to existing populations include feral pigs (*Sus scrofa*).
Engaewa pseudoreducta (Margaret River Burrowing Crayfish)	Critically Endangered	Crayfish (Burrowing)	Perceived	Feral pigs could damage habitat through ground-rooting feeding behaviour and prey on crayfish.
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	Ecological Community	Known	
Temperate Highland Peat Swamps on Sandstone	Endangered	Ecological Community	Known	Main identified threats include damage from introduced animals such as feral pigs (*Sus scrofa*), foxes (*Vulpes vulpes*), dogs (*Canis familiaris*), cats (*Felis catus*), and rabbits (*Oryctolagus cuniculus*)
The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin	Endangered	Ecological Community	Known	
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Critically Endangered	Ecological Community	–	Threat of habitat degradation by feral pigs.
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Critically endangered	Ecological Community		
Temperate highland peat swamps on sandstone	Endangered	Ecological Community		

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	Ecological Community		
The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin	Endangered	Ecological Community		
Chlamydogobius squamigenus (Edgbaston Goby)	Vulnerable	Fish (Freshwater)	Known	
Chlamydogobius micropterus (Elizabeth Springs Goby)	Endangered	Fish (Freshwater)	Known	
Scaturiginichthys vermeilipinnis (Redfin Blue Eye, Redfin Blue-eye)	Endangered	Fish (Freshwater)	Known	
Geocrinia alba (White-bellied Frog, Creek Frog)	Endangered	Frog	Some Perceived, Some Known	Other threats to the white-bellied frogs include habitat destruction by (fire and) feral pigs.
Geocrinia vitellina (Orange-bellied Frog)	Vulnerable	Frog	Some Known, Some Perceived	Potential threats to *G. vitellina* include feral pigs.
Litoria dayi (Lace-eyed Tree Frog, Australian Lacelid)	Endangered	Frog	Perceived	Threatened by potential predation when on the ground (e.g. stream edges and adjacent forest); also habitat damage. This frog is a rainforest species, endemic to the Wet Tropics Bioregion (Williams & Hero 1998, 2001).
Litoria lorica (Armoured Mistfrog)	Critically Endangered	Frog	Perceived	Threatened by potential predation when on the ground (e.g. stream edges and adjacent forest); also habitat damage. The Armoured Mistfrog occurs on the Carbine Tablelands in north-east Queensland where a single population is restricted to 4 km of stream habitat with a total population size of 500-1000 (Hoskin & Puschendorf 2013).
Litoria nannotis (Waterfall Frog, Torrent Tree Frog)	Endangered	Frog	Perceived	Threatened by potential predation when on the ground (e.g. stream edges); also habitat damage. The Waterfall Frog occurs throughout the Wet Tropics Bioregion, North Queensland, from Paluma to Cooktown (Hero & Fickling 1994), but only has stable populations at lowland sites (180-400 m) (Hero et al. 1998, 2002; McDonald & Alford 1999).

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Litoria nyakalensis (Mountain Mistfrog)	Critically Endangered	Frog	Perceived	Feral pigs are a potential cause of riparian habitat damage and adult frog mortality. The Mountain Mistfrog formerly occurred across two thirds of the Wet Tropics Region from Douglas Creek near Cardwell to Alexandra Creek, Thornton Peak, north-east Queensland (Hero & Fickling 1994) at altitudes between 380 and 1020 m (McDonald 1992).
Litoria rheocola (Common Mistfrog)	Endangered	Frog	Perceived	Threatened by potential predation when on the ground (e.g. stream edges and adjacent forest); also habitat damage. The Common Mistfrog historically occurred from Broadwater Creek National Park to Amos Bay, northern Queensland, at altitudes between 0 and 1180 m above sea level (asl) (McDonald 1992).
Litoria olongburensis (Wallum Sedge Frog)	Vulnerable	Frog	Perceived	Other known and potential threats include habitat disturbance and predation by feral pigs. The Wallum Sedge Frog has been recorded in south-east Queensland and north-east NSW and on several other offshore sand islands, including Bribie, Moreton and North Stradbroke Islands.
Mixophyes fleayi (Fleay's Frog)	Endangered	Frog	Known	Large areas of this species' habitat have been and continue to be degraded by feral animals (e.g. feral pigs in the Conondale Range).
Mixophyes iteratus (Giant Barred Frog, Southern Barred Frog)	Endangered	Frog	Known	Threat of predation by feral pigs.
Pseudophryne corroboree (Southern Corroboree Frog)	Critically Endangered	Frog	Perceived	Threat of habitat degradation by feral pigs.
Pseudophryne pengilleyi (Northern Corroboree Frog)	Critically Endangered	Frog	Perceived	Excavation by feral pigs has also been identified as a potentially threatening process for the species.
Spicospina flammocaerulea (Sunset Frog)	Endangered	Frog	Perceived	
Taudactylus pleione (Kroombit Tinker Frog, Pleione's Torrent Frog)	Critically Endangered	Frog	Known	Soil disturbance by feral pigs is also likely to greatly increase the spread of riparian weeds such as mistflower and crofton weed. Feral pigs are also potential vectors of chytrid fungus. At Kroombit Tops, feral pigs have only recently arrived but they have caused significant damage to at least two sites known to support the Kroombit Tinker Frog. Although there may be direct predation by feral pigs, the greatest effect is likely to be the impact of habitat degradation.

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Taudactylus rheophilus (Tinkling Frog)	Endangered	Frog	Perceived	
Liopholis guthega (Guthega Skink)	Endangered	Lizard	Potential	
Nangura spinosa (Nangur Spiny Skink)	Critically Endangered	Lizard		Key threats to the Nangur Spiny Skink include predation by feral animals, including feral pigs.
Pseudomys pilligaensis (Pilliga Mouse, Poolkoo) **Note:** some DNA evidence suggests this species may be an isolated population of the non-threatened delicate mouse (*Pseudomys delicatulus*); this may alter this species' listing in the future, or lead to its de-listing.	Vulnerable	Mammal (Placental)	Known	Threat of habitat degradation by feral pigs.
Xeromys myoides (Water Mouse, False Water Rat, Yirrkoo)	Vulnerable	Mammal (Placental)	Known	
Zyzomys maini (Arnhem Rock-rat, Arnhem Land Rock-rat, Kodjperr)	Vulnerable	Mammal (Placental)	Known	27% of rainforest patches were "severely disturbed" by feral pigs.
Zyzomys palatalis (Carpentarian Rock-rat, Aywalirroomoo)	Endangered	Mammal (Placental)	Known	
Bettongia penicillata ogilbyi (Woylie)	Endangered	Marsupial	Known	Dogs (*Canis familiaris*) and feral pigs (*Sus scrofa*) have also been implicated as the cause of several failed re-introduction attempts. Habitat destruction can also come about from feral pigs.
Bettongia tropica (Northern Bettong)	Endangered	Marsupial	Known	The major threat from invasive species to the northern bettong is competition for hypogeous (underground) fungi from feral pigs
Isoodon obesulus obesulus (Southern Brown Bandicoot (Eastern))	Endangered	Marsupial		Threat of habitat degradation by feral pigs.
Lasiorhinus krefftii (Northern Hairy-nosed Wombat, Yaminon)	Endangered	Marsupial	Perceived	

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Potorous longipes (Long-footed Potoroo)	Endangered	Marsupial	Perceived	Threat of competition with feral pigs.
Caladenia arenaria (Sand-hill Spider-orchid)	Endangered	Orchid	Perceived	There may ... be consumption of the tubers by various animals, such as feral pigs.
Caladenia atroclavia (Black-clubbed Spider-orchid)	Endangered	Orchid	Known	Main identified threat to *C. atroclavia* is feral pigs (*Sus scrofa*).
Caladenia dorrienii (Cossack Spider-orchid)	Endangered	Orchid	Perceived	Main potential threats to cossack spider-orchid include grazing and disturbance by kangaroos and feral pigs. Feral pigs have also caused significant disturbance in the past through diggings and trampling to the habitat at one population.
Caladenia elegans (Elegant Spider-orchid)	Endangered	Orchid	Some Known, Some Perceived	Feral pig activity has been observed in most populations. As well as grazing the orchids themselves, feral pigs can destroy the underground tubers of the orchid and also affect the growth of symbiotic fungi that are essential for germination and for providing starches for the plant (Hoffman and Brown, 1998).
Caladenia hoffmanii	Endangered	Orchid	Perceived	Main potential threats include feral pigs (*Sus scrofa*).
Caladenia tessellata (Thick-lipped Spider-orchid, Daddy Long-legs)	Vulnerable	Orchid	Potential	
Caladenia wanosa (Kalbarri Spider-orchid)	Vulnerable	Orchid	Known	Main identified threats include substrate disturbance by feral pigs (*Sus scrofa*).
Caladenia winfieldii (Majestic Spider-orchid)	Endangered	Orchid	Known	[Feral pigs are] ... affecting the growth of the symbiotic fungi essential for germination and starch provision to the plant. Two remaining populations are threatened by feral pigs.
Caladenia harringtoniae	Vulnerable	Orchid	Known	Other identified threats include grazing by feral pigs.
Diuris pedunculata (Small Snake Orchid, Two-leaved Golden Moths, Golden Moths, Cowslip Orchid, Snake Orchid)	Endangered	Orchid	–	Threat of grazing and/or habitat degradation by feral pigs.

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Diuris venosa (Veined Doubletail, Goat Orchid, Veined Donkey-orchid)	Vulnerable	Orchid	Known	Threatened by damage by feral pigs.
Drakaea concolor (Kneeling Hammer-orchid)	Vulnerable	Orchid	Perceived	Main identified threats to kneeling hammer-orchid include grazing; evidence of feral pigs (*Sus scrofa*) grazing on the species at numerous populations.
Habenaria macraithii (an orchid)	Endangered	Orchid	Perceived	Main potential threats to the species are those that affect its habitat including feral pigs.
Microtis globula (South-Coast Mignonette Orchid)	Vulnerable	Orchid	Perceived	Main potential threat to South-Coast mignonette orchid is feral pigs (*Sus scrofa*) – habitat degradation and grazing.
Phaius australis (Lesser Swamp-orchid)	Endangered	Orchid	Known	Threat of grazing and/or habitat degradation by feral pig; feral pigs, although not thought to be feeding on the swamp orchids, root up the soil whilst searching for food and are especially damaging in Bundjalung National Park, north-east New South Wales.
Phaius bernaysii (Yellow Swamp-orchid)	Endangered	Orchid	Known	... feral pigs have adversely affected ... *Phaius australis* var. *bernaysii*.
Phaius pictus (an orchid)	Vulnerable	Orchid	Perceived	Feral pigs are a potential threat to this species.
Prasophyllum morganii (Mignonette Leek-orchid, Cobungra Leek-orchid, Dense Leek-orchid)	Vulnerable	Orchid	–	Threat of habitat degradation by feral pig.
Pterostylis cucullata (Leafy Greenhood)	Vulnerable	Orchid	–	Threat of habitat degradation by feral pigs.
Pterostylis saxicola (Sydney Plains Greenhood)	Endangered	Orchid	–	Threat of grazing by feral pigs.
Pterostylis sinuata (Northampton Midget Greenhood, Western Swan Greenhood)	Endangered	Orchid	Known	Feral pig activity has been observed in most populations.
Thelymitra dedmaniarum (Cinnamon Sun-orchid)	Endangered	Orchid	Known	As well as grazing the orchids themselves, pigs can destroy the underground tubers of the orchid and also affect the growth of symbiotic fungi that are essential for germination.

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Vappodes lithocola (an orchid)	Endangered	Orchid	Perceived	Some populations may sustain damage from feral pigs (*Sus scrofa*).
Vrydagzynea grayi (Australian population) (an orchid)	Endangered	Orchid	Perceived	Feral pigs are a potential threat.
Zeuxine polygonoides (Velvet Jewel Orchid)	Vulnerable	Orchid	Perceived	Main potential threats include feral pigs.
Asplenium wildii (a fern)	Vulnerable	Plant	Perceived	Main potential threats include feral pigs.
Ballantinia antipoda (Southern Shepherd's Purse)	Endangered	Plant	Known	The feral pigs cause considerable damage to vegetation and soils, including Southern Shepherds Purse habitat.
Baloskion longipes (Dense Cord Rush)	Vulnerable	Plant	Known	Threat of habitat degradation by feral pig – feral pigs (*Sus scrofa*) rooting for food, directly damaging the species and surrounding habitat (CA, 2008).
Burmannia sp. Melville Island (R.Fensham 1021)	Endangered	Plant	Known	
Calotis glandulosa (Mauve Burr-daisy)	Vulnerable	Plant	Known	In the Kosciuszko area, threat of habitat degradation and population loss by feral pigs (CA, 2008).
Chingia australis (a fern)	Endangered	Plant	Known	
Crepidium lawleri (a small plant)	Endangered	Plant	Known	Suffering from disturbance and degradation by feral pigs.
Cynanchum elegans (White-flowered Wax Plant)	Endangered	Plant	Known	Grazing by cattle, goats, rabbits, feral pigs, horses, sheep and deer is affecting remnant patches, causing rapid deterioration of the *C. elegans* habitat.
Diplazium pallidum (a fern)	Endangered	Plant	Known	Main identified threats include feral pigs (*Sus scrofa*).
Diplazium cordifolium (a fern)	Vulnerable	Plant	Known	Damage by feral pigs (but not by direct predation).
Eleocharis obicis (a spike rush)	Vulnerable	Plant	Known	Main identified threats to *E. obicis* include grazing and habitat destruction by feral rabbits (*Oryctolagus cuniculus*) and feral pigs (*Sus scrofa*).

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Eriocaulon carsonii (Salt Pipewort, Button Grass)	Endangered	Plant	Known	Rooting by feral pigs could potentially be the major threat to the species.
Eryngium fontanum (Blue Devil)	Endangered	Plant	Known	
Gardenia psidioides (Hann Gardenia)	Vulnerable	Plant	Perceived	Main potential threats include damage from feral pigs (*Sus scrofa*).
Gentiana baeuerlenii (Baeuerlen's Gentian)	Endangered	Plant	Perceived	Main threats to survival are likely to be damage caused to the area by feral pigs.
Gentiana bredboensis (Bredbo Gentian)	Vulnerable	Plant	Known	Main identified threats include habitat destruction by feral pigs (CA, 2008).
Gentiana wissmannii (New England Gentian)	Vulnerable	Plant	Perceived	Presently disturbance of soil by feral pigs and resulting destruction of vegetation in the swamps and on their margins occurs periodically.
Hoya australis subsp. *oramicola* (a vine)	Vulnerable	Plant	Perceived	The subspecies' habitat, monsoon forests, are vulnerable to feral pigs.
Kennedia glabrata (Northcliffe Kennedia)	Vulnerable	Plant	Known	Main identified threats to Northcliffe kennedia include disturbance from feral pigs.
Lawrencia buchananensis (a plant)	Vulnerable	Plant	Known	Below-ground parts heavily browsed by feral pigs.
Lepidium aschersonii (Spiny Pepper-cress)	Vulnerable	Plant	Known	
Lepidium monoplocoides (Winged Pepper-cress)	Endangered	Plant	–	Threat of habitat degradation by feral pigs.
Mitrella tiwiensis (a vine)	Vulnerable	Plant	Perceived	The subspecies' habitat, monsoon forests, are vulnerable to disturbance from feral pigs
Myriophyllum coronatum (an aquatic plant)	Vulnerable	Plant (Aquatic)	Perceived	Main potential threats include settlement pressures such as feral animals, especially feral pigs (*Sus scrofa*).
Plectranthus torrenticola (a plant)	Endangered	Plant	Perceived	Other possible threatening processes in the future include habitat degradation caused by feral pigs.
Plesioneuron tuberculatum (a plant)	Endangered	Plant	Perceived	Main potential threat to *P. tuberculatum* is feral pigs (*Sus scrofa*).
Reedia spathacea (Reedia)	Critically Endangered	Plant	Known	Main identified threats include predation by feral pigs; feral pigs pose the major threat to the species.

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Rutidosis leiolepis (Monaro Golden Daisy)	Vulnerable	Plant	Perceived	Potential threats within Kosciuszko NP include feral pig activity
Swainsona murrayana (Slender Darling-pea, Slender Swainson, Murray Swainson-pea)	Vulnerable	Plant	Perceived	Other threats include disturbance by feral pigs.
Trachymene scapigera (Mountain Trachymene)	Endangered	Plant	Perceived	Main potential threats to the species include disturbance by feral pigs (*Sus scrofa*).
Typhonium jonesii (a herb)	Endangered	Plant	Perceived	Feral pigs are present on Bathurst Island and have recently been introduced to Melville Island. Feral pigs may potentially dig up the tuber of this species.
Typhonium mirabile (a herb)	Endangered	Plant	Perceived	Feral pigs may potentially dig up the tuber and cause a decline in numbers.
Verticordia fimbrilepis subsp. *fimbrilepis* (Shy Featherflower)	Endangered	Plant	–	
Acacia ammophila (a shrub)	Vulnerable	Shrub	Known	... in the Lake Bindegolly area ... feral pigs threaten the populations by the uprooting of seedlings.
Acacia phasmoides (Phantom Wattle)	Vulnerable	Shrub	Perceived	
Almaleea cambagei (Torrington Pea)	Vulnerable	Shrub	Known	Main identified threats to *Almaleea cambagei* include disturbance of habitat by feral pigs (*Sus scrofa*) and goats (*Capra hircus*).
Astrotricha roddii (a shrub)	Endangered	Shrub	Known	Main identified threats include grazing and habitat disturbance by feral goats (*Capra hircus*) and feral pigs (*Sus scrofa*)
Beyeria lepidopetala (Small-petalled Beyeria, Short-petalled Beyeria)	Endangered	Shrub	Known	
Boronia deanei (Deane's Boronia)	Vulnerable	Shrub	Known	Threat of habitat degradation by feral pig. Main identified threats to Deane's boronia include feral pigs (*Sus scrofa*) which cause direct damage to the species and to its swamp and stream bank habitat.
Callistemon forresterae (Forrester's Bottlebrush)	Vulnerable	Shrub	Potential	
Denhamia parvifolia (Small-leaved Denhamia)	Vulnerable	Shrub	Perceived	Lantana invasion, assisted by fire, feral pig and cattle damage can increase the frequency of hot fires which, in turn, leads to a further increase in density of Lantana.
Grevillea molyneuxii (a shrub)	Endangered	Shrub	Known	Main potential threats to *G. molyneuxii* include digging by animals such as feral pigs (*Sus scrofa*) in the shallow moss and peaty soil of the heathland community.

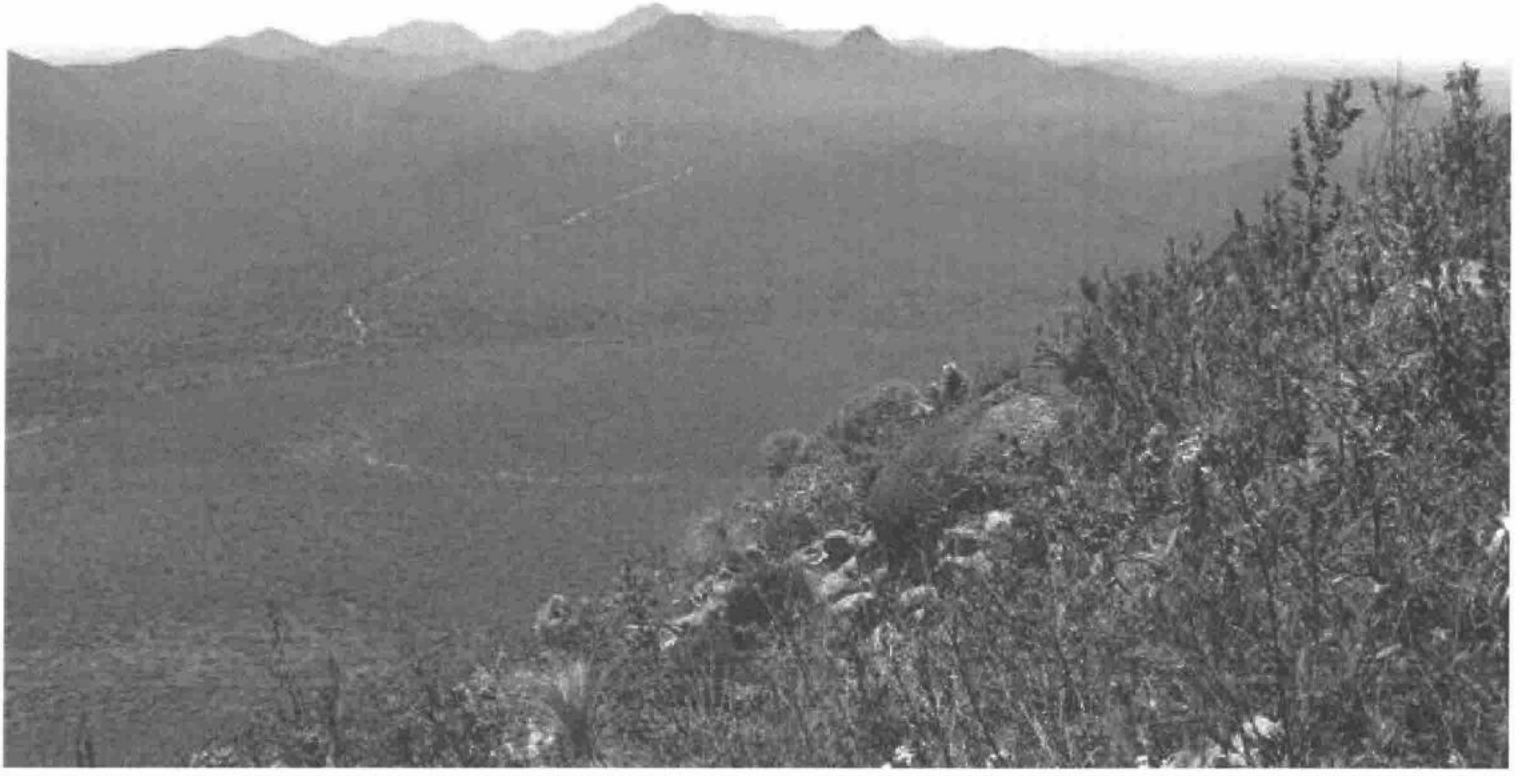
Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Homoranthus prolixus (a shrub)	Vulnerable	Shrub	Known	Habitat degradation by feral pig is identified main threat (CA, 2008).
Hypocalymma longifolium (Long-leaved Myrtle)	Vulnerable	Shrub	Known	Main identified threats include digging and trampling from feral pigs (*Sus scrofa*).
Lechenaultia chlorantha (Kalbarri Leschenaultia)	Vulnerable	Shrub	Known	Main identified threats to Kalbarri leschenaultia include grazing and habitat disturbance by feral pigs (*Sus scrofa*), feral rabbits (*Oryctolagus cuniculus*) and feral goats (*Capra hircus*).
Leucopogon confertus (Torrington Beard-heath)	Endangered	Shrub	Perceived	Possible threatening processes include grazing/digging by feral pigs.
Pimelea curviflora var. *curviflora* (a shrub)	Vulnerable	Shrub	Known	Main identified threats to *Pimelea curviflora* var. *curviflora* include grazing by pest fauna including feral pigs.
Pultenaea parrisiae (Bantam Bush-pea, Parris' Bush-pea)	Vulnerable	Shrub	Known	Main identified threats include damage by feral pigs (*Sus scrofa*).
Solanum dunalianum (a shrub)	Vulnerable	Shrub	Known	Main identified threats include exotic animals, such as feral pigs.
Stachystemon nematophorus (Three-flowered Stachystemon)	Vulnerable	Shrub	Known	Main identified threats include trampling by feral pigs (*Sus scrofa*).
Styphelia perileuca (a shrub)	Vulnerable	Shrub	Perceived	Main potential threats include disturbance by feral pigs (*Sus scrofa*).
Tasmannia glaucifolia (Fragrant Pepperbush)	Vulnerable	Shrub	Known	Main identified threats include grazing and trampling by pigs (*Sus scrofa*).
Tetratheca juncea (Black-eyed Susan)	Vulnerable	Shrub	Known	Threat of grazing by feral pigs.
Xerothamnella parvifolia (a shrub)	Vulnerable	Shrub	Known	Main identified threats include grazing by feral pigs, (*Sus scrofa*).
Xylopia monosperma (a shrub)	Endangered	Shrub	Potential	Main identified threats include feral pigs (*Sus scrofa*).
Gudeoconcha sophiae magnifica (a helicarionid land snail)	Critically Endangered	Snail	Potential	

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Mathewsoconcha grayi (Gray's Helicarionid Land Snail)	Critically Endangered	Snail	Potential	
Mathewsoconcha phillipii (Phillip Island Helicarionid Land Snail)	Critically Endangered	Snail	Potential	
Mystivagor mastersi (Masters' Charopid Land Snail)	Critically Endangered	Snail	Potential	
Pseudocharopa whiteleggei (Whitelegge's Land Snail)	Critically Endangered	Snail	Potential	
Pseudocharopa lidgbirdi (Mount Lidgbird Charopid Land Snail)	Critically Endangered	Snail	Potential	
Quintalia stoddartii (Stoddart's Helicarionid Land Snail)	Critically Endangered	Snail	Potential	
Archontophoenix myolensis (Myola Palm, Myola Archontophoenix)	Endangered	Tree	Perceived	Potential threats identified are feral pigs.
Cadellia pentastylis (Ooline)	Vulnerable	Tree	Known	Main identified threats include grazing and soil compaction by feral pigs.
Gulubia costata (a palm)	Vulnerable	Tree	Perceived	Feral pigs could cause habitat disturbance
Pouteria eerwah (Shiny-leaved Condoo, Black Plum, Wild Apple)	Endangered	Tree	Known	Main identified threats include seed predation by insects and feral pigs.
Sankowskya stipularis (a small tree)	Endangered	Tree	Perceived	Main potential threats to *S. stipularis* include feral pigs (*Sus scrofa*).
Caretta caretta (Loggerhead Turtle)	Endangered	Turtle (Marine)	Known	The main threats are identified as: predation of turtle eggs by native and introduced animals [including feral pigs].
Chelonia mydas (Green Turtle)	Vulnerable	Turtle (Marine)	Known	Threat of predation [eggs and hatchlings] by feral pigs.
Dermochelys coriacea (Leatherback Turtle, Leathery Turtle, Luth)	Endangered	Turtle (Marine)	Potential	Threat of predation [eggs and hatchlings] by feral pigs.

Species or Community Name	EPBC Status	Grouping[2]	Confidence	Comments (may be regionally focussed)
Eretmochelys imbricata (Hawksbill Turtle)	Vulnerable	Turtle (Marine)	Known	Egg predation. Predation of nests by feral pigs occurs in Qld.
Natator depressus (Flatback Turtle)	Vulnerable	Turtle (Marine)	Known	Egg predation. Feral pigs destroy up to 90% of the nests on western Cape York.
Elusor lavarackorum (Gulf Snapping Turtle)	Endangered	Turtle (Freshwater)	Known	Main identified threats to the Gulf Snapping Turtle include disturbance to nesting sites by feral animals, such as feral pigs (*Sus scrofa*).
Rheodytes leukops (Fitzroy River Turtle, Fitzroy Tortoise, Fitzroy Turtle, White-eyed River Diver)	Vulnerable	Turtle (Freshwater)	Perceived	Turtles may be vulnerable to predation by pigs, foxes and dogs if forced to move over land due to artificial barriers communal nesting sites along river banks are now heavily exploited by foxes (*Vulpes vulpes*), feral pigs (*Sus scrofa*), dingos (*Canis lupus*).
Pseudemydura umbrina (Western Swamp Turtle)	Critically Endangered	Turtle (Freshwater)	Known	

Australian Government
Department of the Environment

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



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The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or the Minister for the Environment.

The contents of this document have been compiled using a range of source materials and are valid as at August 2013.

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Photo credits

Front cover: *Mondurup Peak, Stirling Range, 2010* (Department of Parks and Wildlife, Western Australia)
Back cover: *Wildflowers on Mondurup Peak, Stirling Range, 1993* (Rob Olver)

Contents

1. Introduction

This national threat abatement plan (TAP) has been developed to address 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 2001 (Environment Australia, 2001).

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 (Department of the Environment) is responsible for preparing this TAP. Its development has been informed by:

- the current threat abatement plan (published in 2001)
- a review and evaluation of the 2001 TAP undertaken by the Australian Government (CPSM, 2006)
- information provided by key stakeholders between 2010 and 2013.

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, 2014). 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 2013).

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; and recovery actions for the conservation of biodiversity assets currently being impacted.

The Department of the Environment 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 state and territory approaches to managing *P. cinnamomi*.

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.

Although this TAP applies to *P. cinnamomi*, the Department of the Environment acknowledges that recent 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 2014). 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 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, 2014).

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 asymptomatically 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 its impact may be significant before it is detected.

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.

Damaged: These before-and-after images of Mondurup Peak, Stirling Range in Western Australia reveal the effects of Phytophthora cinnamomi on the landscape. (Left: Rob Olver, right: Department of Parks and Wildlife, Western Australia)

Hardham (2005) suggests that *P. cinnamomi* is likely to infect over 2500 Australian native species. In the South-West Botanical Province Shearer et al. (2004) have shown that approximately 41per cent of 5710 vascular plant species are susceptible to the pathogen. 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.

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 of *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).

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).

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 widespread across Tasmania and also occurs within the World Heritage Area.
- 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 threat include:

- The Stirling Range National Park and Porongurup National Park in south-west Western Australia. *P. cinnamomi* is a significant threat to plant communities of outstanding richness and endemicity.
- 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.
- Western Tasmania Aboriginal Cultural Landscape.

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's[2] Man and

2 United Nations Educational, Scientific and Cultural Organisation

the Biosphere Program. The EPBC Act includes provisions for cooperative arrangements between the Commonwealth, states and territories in the development of biosphere reserves.

1.4 Managing the threat

Although *P. cinnamomi* can be eradicated from small sites and containment methods are available to prevent the spread of the pathogen (Dunstan et al., 2011) further work is required to:

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

In order to address the key threatening process listing for *P. cinnamomi* under Section 183 of the EPBC Act, priority must be given to mitigating the impact and minimising the spread of *P. cinnamomi* in areas containing biodiversity assets of high conservation value. These include areas that:

- contain threatened species or ecological communities susceptible to *P. cinnamomi*
- contain 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, for example:

- support high plant species endemicity
- 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, but not under the EPBC Act.

1.4.1 Minimising the spread

Humans can spread *P. cinnamomi* further and faster than any other infestation vector. 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/yabbying
- 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)

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 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 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 up to 10 years, while spraying the leaves provides protection for up to 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 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 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 eradicating *P. cinnamomi* in ecosystems 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*. Careful consideration must therefore be made as to the circumstances under which host destruction methods are appropriate.

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, 2014)).

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 a project to collect and preserve viable seeds in conservation seed banks in Australia (ASBP, 2013), the Department of the Environment 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, can also be employed. This 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. 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. 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 many taxa. Future research may also allow for the transfer of resistance genes into those taxa that at present appear to have no resistance. 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, 2014).

1.5 Climate change

It is difficult to predict how changing climate parameters will impact *Phytophthora* dieback, but it is likely that the distribution and severity of *P. cinnamomi* infestations will be significantly altered because of climate change. 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, 2014).

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 three 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.

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 the 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 species and communities at risk from *P. cinnamomi* through assessing state/territory and Commonwealth lists of threatened species.	Australian Government and state and territory governments	High priority	Short term	Assessment of threatened species and communities that may be impacted completed and the Threatened Species Scientific Committee advised with 12 months of the making of this TAP. Gaps and synergies identified to inform management.
Action 1.2 Identify impacts and prioritise flora, fauna and communities at risk to inform *P. cinnamomi* 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 *Phytophthora* dieback is evaluated in Commonwealth recovery plans.
Action 1.3 Identify risk areas spatially to generate lists of biodiversity assets at risk from *Phytophthora* dieback—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: • maps of potential national distribution of pathogen • maps of priority biodiversity assets.
Action 1.4 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 1.5 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 *Phytophthora 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 *P. cinnamomi* 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 *P. cinnamomi*.	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). *Ex situ* conservation of species at risk is undertaken at appropriate facilities that manage the risk of *P. cinnamomi* introduction.

Action	Responsible party	Priority	Timeframe	Performance indicators
Action 2.3 Develop and implement practices to minimise the inadvertent spread of *P. cinnamomi* to priority biodiversity assets.	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)	High priority	Short term and ongoing	Risk reduction plans (prevention, impact reduction, containment, stakeholder engagement, communication materials including signage, monitoring) for priority protection areas and biodiversity assets are prepared. Implement a voluntary certification scheme Australia-wide for high risk materials such as nursery materials, soils, quarry products and road and track building material. Pathogen-tested raw materials, compliant with a best practice certification scheme, are used in high-risk infestation pathways such as soil and nursery materials.
Action 2.4 Integrate management of *P. cinnamomi* with other natural resource management systems.	Australian Government and state and territory governments	Medium priority	Medium term	State and territory governments have adopted integrated hygiene procedures for works in native vegetation to manage pests, weeds and disease risks. *P. cinnamomi* management is integrated with other compatible land management programs such as revegetation, fire, weed and pest management and road maintenance programs.
Action 2.5 Prepare guidelines to minimise risks from *P. cinnamomi* arising from Australian Government environment funding programs.	Australian Government	High Priority	Medium term	Guidelines to minimise risks from *P. cinnamomi* arising from Australian Government environment funding programs are developed and communicated within 12 months of making this TAP.

Objective 3: Communication and training

Many people are unaware of the significance of *P. cinnamomi* and the ways it can be spread. Ongoing delivery of awareness and capacity building programs in natural resource management at national, state and regional level can make a significant contribution to national implementation of the TAP.

In order to inform and empower stakeholders, particularly land managers and land users, to take actions that collectively minimise the spread and reduce the impacts of *P. cinnamomi* it is necessary to effectively communicate:

- the approach adopted in this TAP
- the scale of the threat to biodiversity posed by *P. cinnamomi*
- the priority biodiversity assets that need protection
- information for land managers, recreational users, ecotourism operators and other stakeholders on 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 Determine stakeholders, key messages and the most efficient means of communicating with stakeholders on issues relating to *P. cinnamomi* impacts on priority biodiversity assets.	Australian Government and state and territory governments	High priority	Medium term and ongoing	Effective communication actions are progressed during the life of 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 *P. cinnamomi* 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 *P. cinnamomi* 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 *P. cinnamomi* infested material.
Action 3.3 Ensure that guidelines, including codes of practice and standard operating procedures, for managing *P. cinnamomi* are available to key stakeholders and are implemented, reviewed and updated.	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
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 *P. cinnamomi* in priority areas.
Action 3.5 Acquire and maintain up to date information on *P. cinnamomi* and the progress of the TAP.	Australian Government	Medium priority	Ongoing	The Department of the Environment website holds and maintains up to date information reflecting the achievements against TAP actions. The Department of the Environment hosts a forum with key stakeholders to assist in implementation of the plan and to review achievements of the plan. The Department of the Environment reviews research actions, disseminates new information and promotes the uptake of findings.

Research actions

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.

Action	Responsible party	Priority	Timeframe	Performance indicators
Research action 1 Encourage new partnerships (e.g. through the Australian Research Council or forestry, mining and nursery industries) to support the funding of research relating to the management of *P. cinnamomi* (and other *Phytophthora* species).	Australian Government, state and territory governments, research organisations and industry	High priority	Ongoing	Partnerships are initiated within 12 months of this TAP being made.
Research action 2 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 *P. cinnamomi*, assessing its long term direct and indirect impacts in the range of priority ecosystems it affects.
Research action 3 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 *ex situ* programs (where available). Infested sites are monitored for resistant individuals or populations to enable the sourcing of material for resistance screening.
Research action 4 Develop improved techniques for rapid diagnosis of *P. cinnamomi* 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 *P. cinnamomi* infestations are evaluated for use in natural ecosystems. Cost effective and accurate methods for the rapid diagnosis of *P. cinnamomi* species are available.

Action	Responsible party	Priority	Timeframe	Performance indicators
Research action 5 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 *P. cinnamomi* from small, infested sites are identified and assessed for their relative efficacy. The efficacy of phosphite in the control of *P. cinnamomi* across a range of susceptible ecological communities is determined. The effects of phosphite on non-target species are identified. Alternatives to phosphite for controlling *P. cinnamomi* are identified and their relative efficacy assessed. This may include, but is not limited to: potential biocontrol options and other chemicals to augment/ supplement phosphate. The efficacy of hygiene protocols for controlling disease spread are assessed and implementation improved (this could include the efficacy of implementation practices).
Research action 6 Undertake further (new) research into efficient and cost effective (nationally applicable) techniques for: • eradication methods for soil types other than porous soils (for which a method exists) • management of impact through transferring resistant genes into taxa that show little resistance to *P. cinnamomi*.	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	Responsible party	Priority	Timeframe	Performance indicators
Research action 7 Develop methods for restoration of priority sites that are degraded by *P. cinnamomi*.	Australian Government, state and territory governments and research organisations	Medium priority	Ongoing	Novel restoration and revegetation techniques for priority sites degraded by *P. cinnamomi* are developed over the life of this TAP, using resistant plant species. Resistant species that may provide structure and food sources for priority species are introduced into impacted priority areas.
Research action 8 Establish repositories for collections of *P. cinnamomi* cultures and nationally available standards for collection and analysis of *P. cinnamomi* samples, in order to facilitate research on the genetic basis of resistance and genetic diversity of *P. cinnamomi*.	Australian Government, state and territory governments and research organisations	Medium priority	Medium term	Cultures of *P. cinnamomi* are able to be tested against samples available through a complete and accessible national repository for cultures of *P. cinnamomi* isolated from natural ecosystems. National standard methods are used by laboratories for the collection and analysis of soil, plant and water samples for the presence of *P. cinnamomi*.

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 allocates its annual budget to a range of competing biodiversity conservation priorities. The budget provided by The Department of the Environment for the implementation of individual TAPs may vary from year to year as a range of biodiversity conservation priorities are addressed.

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 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 *Environment Protection and Biodiversity Conservation Act 1999* 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	*Environment Protection and Biodiversity Conservation Act 1999* (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	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. The eight matters of national environmental significance protected under the EPBC Act are: • 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		
Borya mirabilis	E	Vic.
ASTERACEAE		
Olearia pannosa subsp. *pannosa*	V	SA
ARAUCARIACEAE		
Wollemia nobilis	E	NSW
CASUARINCEAE		
Allocasuarina fibrosa	V	WA
EPACRIDACEAE		
Andersonia axilliflora	E	WA
Andersonia pinaster	V	WA
Epacris apsleyenis	E	Tas.
Epacris barbata	E	Tas.
Epacris exserta	E	Tas.
Epacris glabella	E	Tas.
Epacris graniticola	CE	Tas.
Epacris grandis	E	Tas.
Epacris limbata	CE	Tas.
Epacris stuartii	CE	Tas.