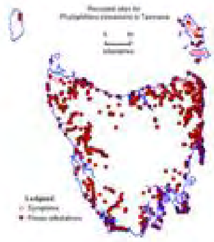

Management of *Phytophthora cinnamomi* for Biodiversity Conservation in Australia

Part 1 - A Review of Current Management

Natural Heritage Trust
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An Australian Government Initiative

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Photos on cover courtesy of: Renate Velzboer, SA DEH; Tim Rudman, DPIWE Tasmania; Emer O'Gara, CPSM WA; Bryan Shearer, CALM WA; Des Peters, Parks Victoria, Victoria.

ABBREVIATIONS

ACT	Australian Capital Territory
Alcoa	Alcoa World Alumina Australia
ARC	Australian Research Council
CALM	The Department of Conservation and Land Management, Western Australia
CPSM	Murdoch University, Centre for Phytophthora Science and Management
CRC PBMDS	Cooperative Research Centre for Plant Based Management of Dryland Salinity
CRC TREM	Cooperative Research Centre for Tropical Rainforest Ecology & Management
CRC TPP	Cooperative Research Centre for Tropical Plant Protection
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCC	Dieback Consultative Council of Western Australia
DEH	Australian Government Department of the Environment & Heritage
DPIWE	Tasmanian Department Primary Industries, Water and Environment
DSE	Department of Sustainability and Environment
DWG	Dieback Working Group
EMS	Environmental Management Systems
EPBC Act	Australian Government Environment Protection and Biodiversity Conservation Act, 1999
EPPO	European and Mediterranean Plant Protection Organisation
GIS	Geographic Information Systems
GPS	Global Positioning System
GTSpot	Geo Temporal Species Point Observations Tasmania database, accessible through the Parks and Wildlife GIS Web Server
IUCN	The World Conservation Union
NAPSWQ	National Action Plan for Salinity and Water Quality
NHT-RCC	National Heritage Trust Regional Competitive Component
NIASA	Nursery Industry Accreditation Scheme Australia
NRM	Natural Resource Management
NSW	New South Wales
NTAP	The National Threat Abatement Plan for Dieback Caused by the Root Rot Fungus *Phytophthora cinnamomi*

PCR	Polymerase Chain Reaction
QPWS	Queensland Parks and Wildlife Service
SA	South Australia
SA DEH	South Australian Government Department for Environment & Heritage
SARDI	South Australian Research and Development Institute
SCRIPT	South Coast Regional Initiative Planning Team
TASVEG	Tasmanian floristic database
TPWS	Tasmanian Government Parks and Wildlife Service
Trust	National Heritage Trust
WA	Western Australia
WHA Veg	World Heritage Area Vegetation database
WTMA	Queensland Government Wet Tropics Management Authority

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1 INTRODUCTION

Disease in natural ecosystems of Australia, caused by the introduced plant pathogen *Phytophthora cinnamomi*, is listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Act requires the Australian Government to prepare and implement a threat abatement plan for nationally coordinated action to mitigate the harm caused by *P. cinnamomi* to Australian species, particularly threatened flora, fauna and ecological communities. The 'National Threat Abatement Plan for Dieback Caused by the Root-Rot Fungus *Phytophthora cinnamomi*' (NTAP) was released in 2001 (Environment Australia, 2001). The NTAP is designed to promote a common understanding of the national threat *P. cinnamomi* poses to biodiversity in Australia.

This project, funded by the Australian Government Department of the Environment and Heritage (DEH), is one of the most significant actions to be implemented from the NTAP to date. The project has two major components:

- to review current management approaches and identify benchmarks for best practice
- the development of risk assessment criteria and a system for prioritising management of assets that are or could be threatened by *P. cinnamomi.*

The project outputs are presented in a four-part document entitled **Management of *Phytophthora cinnamomi* for Biodiversity Conservation in Australia:**

Part 1 – A Review of Current Management (this document)

Part 2 – National Best Practice Guidelines

Part 3 – Risk Assessment for Threats to Ecosystems, Species and Communities: A Review

Part 4 – Risk Assessment Models for Species, Ecological Communities and Areas.

A model of best practice was developed which encompasses all the components necessary for an informed and integrated approach to *P. cinnamomi* management, from strategic through to on-ground management. The current document (Part 1 – A Review of Current Management) thoroughly reviews the approaches to *P. cinnamomi* management in Australia within the context of the best practice model.

2 A MODEL FOR BEST PRACTICE MANAGEMENT OF *Phytophthora cinnamomi*

A best practice model for *P. cinnamomi* management in natural ecosystems of Australia (Figure 2.1) was adapted from a model developed for best practice of cultural heritage management for parks and protected areas in Australia and New Zealand (Hague Consulting, 2001). The model represents all the components of management that are necessary to achieve an integrated and consistent approach for the effective long-term management of *P. cinnamomi* for biodiversity conservation in Australia.

Best practice management of *P. cinnamomi* will be driven by strategic management which includes statutory provisions mainly at the Australian and State Government level, and non-statutory instruments led primarily by State Governments and relevant agencies. Strategic management involves the formal and official acknowledgement by governments that *P. cinnamomi* is a serious environmental and management issue, by providing guidance on how it will be managed, and making provisions for appropriate investment.

Effective strategic management paves the way for the development of the processes and procedures that are necessary for effective on-ground management including: a thorough assessment of the threat and the development of priorities for management, ensuring staff are suitably qualified to implement process and procedures, liaison with other stakeholders including the community, and implementation of standard prescriptions. A process, by which success in achieving management objectives is monitored and measured, will complete a feedback loop of continuous improvement to strategic management. A central core of coordinated and collaborative research underpins the entire management process.

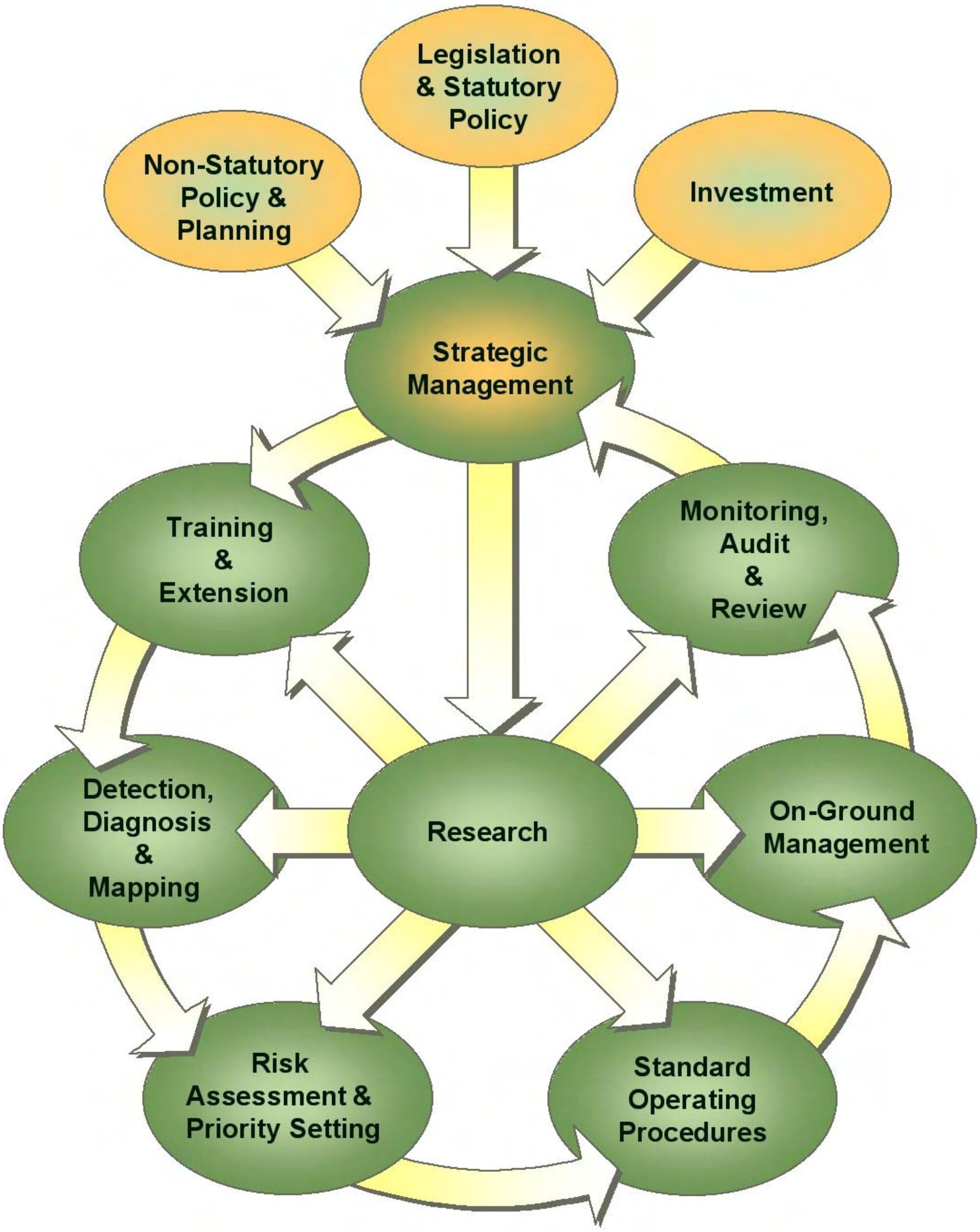

Figure 2.1 A best practice model for the management of *Phytophthora cinnamomi* for biodiversity conservation in natural ecosystems of Australia.

3 REVIEW OF CURRENT MANAGEMENT

3.1 Strategic Management

Strategic Management refers to legislation, statutory and non-statutory policy, planning related to, and investment in, *P. cinnamomi* management. The Australian and State Governments have the key leadership role in the strategic management of a national key threatening process such as *P. cinnamomi*. Collectively, the components of strategic management provide: official acknowledgement that *P. cinnamomi* is a threat to Australia's biodiversity and the tools to manage it.

3.1.1 *Legislation and Statutory Policy*

Legislation that influences the management of *P. cinnamomi* is most commonly enacted by the Australian and State Governments. The mechanism for national protection of biodiversity is the Australian Government *Environment Protection and Biodiversity Conservation Act 1999*, under which *P. cinnamomi* is listed as a national 'key threatening process' and under the provisions of which the National Threat Abatement Plan (NTAP) was developed in 2001. The NTAP is deigned to foster coordinated national management of *P. cinnamomi* and is due for review in 2006. Activities that may threaten species and communities listed under the EPBC Act must be referred to the Australian Government Department of the Environment and Heritage (DEH). However, the capacity to assess the potential impact of *P. cinnamomi* is limited by a poor understanding of the extent to which *P. cinnamomi* affects biodiversity, particularly threatened taxa, and significant gaps in fundamental knowledge about the pathogen and its interaction in the environment.

Statutory tools for environment and biodiversity conservation differ from State to State. Within States, coordination between relevant agencies to manage *P. cinnamomi* is generally poor. However, Western Australia (WA) is currently working toward a whole-of-government policy linked to the WA *Environmental Protection Act 1986* which will extend the powers to actively manage the pathogen beyond the conservation estate. As *P. cinnamomi* cannot be eradicated from a site, responding after an introduction has occurred is, in most instances, too late for the community being infested. There is need for statutory powers to be proactive (triggered to prevent an introduction), rather than reactive (triggered after damage has occurred due to an introduction).

Currently, the ability to regulate access to public lands for environmental protection is one of the most powerful statutory tools for *P. cinnamomi* management. Although, legislation in a number of States provides for this, its use is limited in some States by poor public understanding of the issue, opposition to changes in land-use and the need for enforcement. A greater awareness is needed amongst land management agencies about the implications for *P. cinnamomi* management of interrelatedness of legislation. Some Australian Government legislation, governing the proponents of potentially high risk activities, overrides State legislation and greater engagement of such proponents is urgently needed.

Current Practice in Legislation and Statutory Policy

The Australian Government's mechanism for national environment protection and biodiversity conservation is the Australian Government *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), under which *P. cinnamomi* is listed as a national 'key threatening process'. Actions that may threaten species and communities listed under the Act must be referred to the DEH and approval for such actions may be denied or may be granted with the inclusion of measures for risk mitigation.

The NTAP, the preparation of which was a requirement of the EPBC Act, describes how the Australian Government will act to abate the threat of *P. cinnamomi* in Australia, through the declaration of its goals, objectives and plans for coordinated actions (Environment Australia, 2001). The current project to develop best practice benchmarks and a risk assessment tool for *P. cinnamomi* management has been one of the most significant actions of the NTAP to be implemented to date.

Although knowledge about *P. cinnamomi* and its management has being developing over the past 40 years amongst land managers and scientists, the 2001 release of the NTAP has raised general awareness of the pathogen and its impact, and has given authority to actions of those responsible for threat abatement. The threat abatement plan for *P. cinnamomi* is one of only eight approved NTAPs. The NTAP has provided funding (approximately $566,000 since its release) for discrete projects on *P. cinnamomi* in a number of States as part of its implementation.

Two pieces of State legislation formally recognise *P. cinnamomi* as a key threatening process to biodiversity: the NSW *Threatened Species Conservation Act 1995* and the Victorian *Flora and Fauna Guarantee Act 1988*. The Victorian Act is not restricted by tenure and addresses biodiversity issues on both public and private land.

As human vectoring is the greatest cause of spreading *P. cinnamomi* to uninfested areas, the most effective legislation will empower land managers to regulate human access. Regulating access may involve temporary restrictions, for instance when the probability of successful transfer and establishment of the pathogen is high, or may require permanent quarantine of areas. Western Australia, Tasmania and South Australia have legislation that empowers the State land managers to quarantine areas, which is primarily used to protect areas of high conservation values from various threats, including *P. cinnamomi*.

In Tasmania, the provisions of the Tasmanian *Plant Quarantine Act 1997* allow for the establishment of 'Protected Areas' to direct measures for the protection of that area from a plant pathogen. To date, this provision has been applied only once, for the protection of a threatened plant species in Tasmania (Rudman, 2004).

The South Australian Government and the Department for Environment and Heritage have been supportive of gazetting areas through the SA *National Parks and Wildlife Act 1972*, and the imposition of fines for breaches of the quarantine conditions, to minimise the spread of *P. cinnamomi* from designated areas (R Velzeboer, *pers. comm.*).

The Queensland *Plant Protection Regulation 2002* is the only Queensland legislation which gives specific reference to *P. cinnamomi*. It lists *P. cinnamomi* as a prescribed pest, with trade in plants known to be infested made illegal. However, this regulation is directed primarily at *P. cinnamomi* as an agricultural pathogen. The principal act governing management of protected lands and wildlife is Queensland's *Nature Conservation Act 1992.* The Queensland Parks and Wildlife Service (QPWS), and its umbrella organisation, the Environmental Protection Agency, administer this Act. With respect to National Parks, the stated cardinal management principle is to provide, to the greatest possible extent, for the permanent preservation of the area's natural condition and the protection of the area's cultural resources and values.

Under the Queensland *Environmental Protection Act 1994*, the QPWS has a duty of care to prevent foreseeable environmental harm including that caused by threatening processes. Although the Queensland *Nature Conservation Act 1992* does not give specific mention to the pathogen, it states clear management intents for National Parks and other types of protected areas in the State, and provides specifically for the reduction or removal of threatening processes relating to protected wildlife.

Queensland State Forests and Timber Reserves are State lands managed under the Queensland *Forestry Act 1959.* The cardinal management principle observed in the management of State forests is that they are permanently reserved for the purpose of producing timber and associated products, and protecting watersheds therein. Management intent is, thus, more "user oriented"; however, provisions exist in the map for development and implementation of tactics that may limit the spread of *P. cinnamomi.*

In WA, the Government Department of Conservation and Land Management (CALM) is responsible for the administration and implementation of the WA *Wildlife Conservation Act 1950* and the WA *Conservation and Land Management Act 1984*, that together provide the primary legal basis for conservation of biodiversity on Crown conservation lands (CALM, 2003). The WA *Conservation and Land Management Act 1984* provides gazettal for the quarantine of specific areas of State Forest (referred to as 'Disease Risk Areas') for the purpose of protection from *P. cinnamomi*.

The WA Government is currently proposing two changes to State legislation that will improve the provisions for biodiversity conservation generally, and *P. cinnamomi* management specifically. In recognition that the WA *Wildlife Conservation Act 1950* is in need of reform and does not provide an adequate legislative basis for biodiversity conservation in the State, a new Biodiversity Conservation Act for WA has been proposed (CALM, 2002). This has been released for public comment and the Bill is currently being drafted. The new Act may require development of a State Biodiversity Conservation Strategy, which provides for the development of abatement plans for all major threatening processes including *P. cinnamomi* (CALM, 2004a).

The WA *Environmental Protection Act 1986* has been revised and reformed by the WA *Environmental Protection Amendment Act 2003* to bring it to the forefront of environmental legislation in Australia (DoE, 2003; DoE, 2004). Among the changes that have the potential to impact on the management of *P. cinnamomi* is the new offence for causing unauthorised environmental harm which carries severe penalties (DoE, 2004). Environmental harm is defined for the purposes of the Act as the 'alteration of the environment to its detriment or degradation' and includes 'potential detriment or degradation' to enable preventative action to be taken (DoE, 2004).

There are currently no States in Australia with statutory policies for the management of diseases in natural ecosystems caused by *P. cinnamomi*. However, recent amendments to the WA *Environmental Protection Act 1986* will enable the Environment Minister to pursue a whole-of-government policy on dieback management as outlined under the Dieback Response Framework (CALM website – Media Statement, accessed 13/02/05).

A whole-of-government approach to dieback management is currently under investigation, through the development of a State Environmental Planning Policy, and is considered a critical component of an integrated approach to *P. cinnamomi* management in Western Australia (WWF and DCC, 2004). In WA, Environmental Protection Policies (EPPs) are developed under the *Environmental Protection Act 1986* (WA). They are whole-of-government policies that have powers as if part of the Act (EPA, 2004a). They have been used by the WA Government to address environmental issues that could not otherwise be adequately addressed via other provisions of the Act and have varied in their degree of coerciveness and success (EPA, 2004a). The amendments to the WA *Environmental Protection Act 1986* enables overarching state-wide statutory policies to be developed that address sources of environmental harm other than pollution (EPA, 2004b) which will assist the proposal by the Environment Minister to pursue a whole-of-government approach.

Although the *Conservation and Land Management Act 1984* (WA) cannot impose restrictions on mining or development projects subject to a State Agreement Act (McNamara, 2002), the *Environmental Protection Act 1986* (WA) can now override State Agreement Acts (J Bailey, *pers. comm.*).

Gaps in Current Legislation and Statutory Policy

Two key gaps in the current statutory provisions for the management of *P. cinnamomi* in Australia are: the absence of statutory policy at State Government level, and relevant legislation in many States that is restricted to lands of certain tenure. Until very recently, poor policy development has been attributed to the lack of knowledge and technical expertise in *P. cinnamomi* management in many State conservation agencies. A continuing problem within many State conservation agencies is that suitably qualified staff has part-time, temporary or unofficial responsibility for issues of *P. cinnamomi* management.

Inadequate information about the threat *P. cinnamomi* poses to natural ecosystems is major impediment to the formulation of effective statutory instruments by governments. The poor level of public awareness about the actual and potential impact of the pathogen can be a major impediment to the success of the provisions. Both can result in poorly coordinated and ineffective management of the pathogen and protection of natural values at risk.

The triggering of action by the NSW *Threatened Species Conservation Act 1995* relies on knowledge and awareness of the extent of the threat posed by *P. cinnamomi* in the State. Although the Act lists *P. cinnamomi* as a 'key threatening process', a threat abatement plan is an option, but not a requirement. In the absence of a threat abatement plan, action on *P. cinnamomi* is only triggered if the pathogen is a threat to species that are proposed for listing, or if it is listed as a threat in a recovery plan for a species/community. Currently *P. cinnamomi* is listed as a threat in only one NSW recovery plan (K McDougall, *pers. comm.*), probably because until quite recently *P. cinnamomi* has been considered benign in NSW. There is currently limited knowledge of the distribution of the pathogen and the vulnerability of species and communities.

As mentioned above, statutory protection of threatened species and ecological communities can depend on their listing under the EPBC Act or relevant State Acts. However, legislation in WA and Tasmania does not currently recognise threatened ecological communities (CALM website – Threatened Species and Threatened Ecological Communities, accessed 19/12/04; DPIWE, 2000). Another significant problem is the lengthy processes in some States to get threatened taxa listed.

State legislation that empowers land managers to quarantine areas or restrict access to lands is potentially a very powerful management tool. However, legislation that provides for such action, e.g. the WA *Conservation and Land Management Act 1984* and the Tasmanian *Plant Quarantine Act 1997,* can be limited by a need for enforcement (K Vear and T Rudman, *pers. comm.*). Changes to land use are often unpopular in the community, particularly where changes involve restricted access to public lands. Due to political ramifications public opposition may result in difficulty in obtaining Ministerial or Departmental approval to use such provisions. Alternatively, when restrictions are imposed public opposition may be expressed through breaching of entry conditions, which most Departments have neither the resources nor political will to enforce. The role of public education cannot be over emphasised here, as a low level of public awareness and understanding of the impacts of the disease will exacerbate non-compliance.

The effective conservation of biodiversity in Australia is also hampered by outdated legislation. The *Wildlife Conservation Act 1950* (WA) is the oldest of its kind in Australia and is currently the main law protecting natural plant and animal species in WA. However, it does not provide for the protection of ecological communities or populations, and has limited measures to protect threatened species including no statutory mechanisms for creating recovery plans (EDO, 2000). Replacement legislation has been drafted that will address this deficiency (CALM, 2004a).

A greater awareness is needed amongst land management agencies about the implications for *P. cinnamomi* management of interrelatedness of legislation. Some Australian Government legislation, governing the proponents of potentially high risk activities such as the laying of telecommunication cables, overrides State legislation and greater engagement of such proponents is urgently needed.

3.1.2 *Non-Statutory Policy and Planning*

Non-statutory policy and planning refers to documents that describe the voluntary course of action to be followed by an organisation to achieve its objective for *P. cinnamomi* management. The triggers necessary to ensure that *P. cinnamomi* is considered in planning processes are generally agreed to be inadequate in Australia.

There is little consistency between States in the scope or processes of *P. cinnamomi* management, although many States have looked to the considerable experience of WA in developing standard operating procedures and other policy and planning tools. CALM in WA has developed a range of policy and planning tools, initially for management of *P. cinnamomi* in forestry operations, but which have been extended in recent years to management of *P. cinnamomi* in the broader conservation estate.

Policy and planning in relation to the management of *P. cinnamomi* is very limited at a Local Government level in most States, with the exception of some Shires in WA. The non-government, community based WA Dieback Working Group (DWG) has worked in an extension role to channel information and technologies produced by CALM and the mining industry in WA to other stakeholders, particularly Local Government, high risk industries and the general community. Codes of Practice have been developed in WA and Tasmania for, and in collaboration with, the extractive industries. However, Codes of Practice are needed in all States for a wider range of high risk industries, especially those operating in areas of high conservation value.

Current Practice in Non-statutory Policy and Planning

Although there is currently no State with statutory policy governing the management of disease caused by *P. cinnamomi* in natural ecosystems, non-statutory policy or planning processes have been developed to some degree in nearly all States affected by the pathogen. These documents/processes have been produced by: State Governments, State conservation agencies, Local Government, and consortiums of government, industry and the community.

In line with the NTAP, Tasmania and Victoria have developed State strategic plans. In Tasmania, a regional approach to strategic planning for *P. cinnamomi* management was developed primarily for lands managed by Tasmanian Parks and Wildlife Service (TPWS) or Forestry Tasmania (Schahinger *et al.,* 2003). Based on the occurrence of National or State listed susceptible species, the Plan prioritises 67 areas and makes area-specific recommendations for *P. cinnamomi* management (Schahinger *et al.,* 2003). Rather than develop its own Threat Abatement Plan, Tasmania directly utilises the NTAP to implement projects like those of Schahinger *et al.* (2003).

The strategic plan for Victoria is currently in draft and provides a three-year program for cross-tenure actions to curb the spread of *P. cinnamomi* and identify significant vulnerable areas of the State for protection from infestation (DSE, 2004). The strategy for curbing the spread includes the formulation and promotion of best practice management of *P. cinnamomi* in plant nurseries and other industries that have the potential to spread infested soil and water (DSE, 2004).

Although *P. cinnamomi* is a prescribed pest organism in Queensland (which prevents trade in plants known to be infested), there has been little attention given to managing the pathogen from the point of view of natural ecosystems. The exception to this case is the Wet Tropics World Heritage Area where, since 1997, the pathogen has been identified as a potential threat to the World Heritage values of the area.

Driven by the Wet Tropics Management Authority (WTMA), an ongoing program of research has lead to the development of draft operational guidelines for works within the identified high-risk zones of the Area (Worboys and Gadek, 2004), based upon the management guidelines developed by the WA DWG (DWG, 2000) guidelines. No formal measures currently exist that trigger the implementation of these hygiene guidelines. However, operational works can only be undertaken under a Wet Tropics Permit, issued by WTMA.

Strategic planning for the threat abatement of *P. cinnamomi* in WA is not embodied in a single document. Instead, a State Government initiated Dieback Response Framework has been developed in which government and non-government agencies are working together to channel their various activities and responsibilities for effective and coordinated management and research. The key instruments of strategic planning in WA are the WA Dieback Consultative Council (CALM website) and the recently launched Dieback Response Framework (CALM website).

The WA Minister for the Environment appointed the Dieback Consultative Council (DCC) in 1997 to provide specialist advice on issues relating to *P. cinnamomi* in WA including: research, management and funding priorities for the State, policy revision and development for CALM and the State, and participation in the NTAP. Key stakeholders from government, industry, research and the community are represented on the DCC. The DCC assisted the WA Government in the development of the Dieback Response Framework which was launched by the State Minister for the Environment in 2004.

Key strategies of the Dieback Response Framework which are currently being implemented include the development of:

- a dieback atlas for WA
- management guidelines for use on all land tenures
- a generic dieback risk assessment methodology
- an action plan specifically to tackle the dieback threat to areas such as the Fitzgerald River National Park
- a whole-of-government policy on dieback management.

CALM in WA (CALM, 2004b) and Parks Victoria (Parks Victoria, 1998) have produced discrete policy statements on the management of *P. cinnamomi* for lands vested in them. CALM policy on *P. cinnamomi* management has been developed over 40 years with numerous reviews and modifications (Dell *et al.,* 2005). The current CALM policy (CALM, 2004b) and guidelines for best practice management of *P. cinnamomi* (CALM, 2004c) are yet to be finalised after a period of public consultation (CALM website – Dieback Response Framework, accessed 13/01/05). The process of consulting was identified as best practice, in the development of policies, strategies and plans for management of cultural heritage assets (Hague Consulting, 2001).

The CALM policy statement (CALM, 2004b) acknowledges that it is not possible, with the current state of information, to eradicate *P. cinnamomi* and that a 'less optimistic' but more realistic objective is to focus management on what is considered 'protectable' (CALM, 2003). What constitutes 'protectable' is discussed further in Section 3.5 Risk Assessment and Priority Setting.

The Parks Victoria policy states that: "All reasonable and necessary steps to reduce the impact of *P. cinnamomi* in those areas already infested, and protect susceptible but uninfested areas from its introduction as necessary", and identifies the Chief Rangers as responsible for ensuring all staff understand and comply with the policy (Parks Victoria, 1998). Parks Victoria commissioned best practice guidelines for the management of *P. cinnamomi* in Victorian parks and reserves (Cahill *et al.,* 2002), which have become an important internal reference and will be referred to in the revised Parks Victoria *P. cinnamomi* policy (D Peters, *pers. comm.*).

In the last 10-15 years there has been increasing pressure for Local Governments to improve their environmental performance (Dell *et al.,* 2005). The activities undertaken by Local Government such as road/drain construction and maintenance, and bushland reserve management have the potential to introduce *P. cinnamomi* to previously uninfested areas, or increase its rate of spread from areas that are infested (DWG, 2000). However, until recently, *P. cinnamomi* was considered by Local Governments in WA as too difficult and costly to address (Lewis *et al.,* 2000).

Since 1996, the WA DWG, whose membership includes community groups, Local Government authorities and State Government agencies, have been working with Local Governments to educate and promote the uptake of *P. cinnamomi* management measures. In 2000, they released guidelines for the management of *P. cinnamomi*, which includes suggestions for goals and appropriate objectives, policies, strategies and actions, which can be customised and adopted by Local Government (DWG, 2000). Two years after the release of the Guidelines, the WA DWG reported that six councils out of 30 in metropolitan Perth have adopted guidelines, and 3 were in the process of drafting policies on *P. cinnamomi* management (Zuvela, 2002).

The Shire of Mundaring was one of the founding members of the WA DWG (Lewis, 2000). Situated on the outskirts of Perth, the Shire contains significant areas of natural vegetation of high conservation value that are under threat from *P. cinnamomi* (McCarthy, 2005a). The Shire has adopted a policy to minimise the probability of introducing and spreading *P. cinnamomi* and developed a range of policy implementation tools including a dieback assessment process, dieback procedures and guidelines for staff and contractors, a training program and process for compliance checking (McCarthy, 2005a).

Non-government organisations or individuals that own or lease lands that are subject to the threat of *P. cinnamomi* may chose to, or may be required to, develop *P. cinnamomi* management strategies as part of their lease arrangements. Jandakot Airport Holdings P/L has developed an Environmental Strategy under the terms of an agreement to lease a site south of Perth in WA (Jandakot Airport website - Environmental, accessed 03/02/05). The site contains 410ha of natural bushland which is generally in very good condition, but contains localised pockets of *P. cinnamomi* infestations with a high probability of spread due to an extensive track network (Glevan Dieback Consultancy Services, 2000; M Butland, *pers. comm.*). The Company has developed a disease management plan, hygiene policy and guidelines for staff and contractors, instituted staff training through the WA DWG, and have integrated hygiene procedures into the bushfire management plan.

The Codes of Practice developed in Tasmania and WA for, and with, the extractive industries (DPIWE & DIER, 1999; DWG, 2004a; DWG, 2004b), aim to promote self regulation in the industry. The Code of Practice for the management of reserves in Tasmania is designed to promote consistency in the application of management practices by staff of key land management agencies (TPWS, FT & DPIWE, 2003). It provides 'best practice operational standards' for all activities, including plant disease management which reserve managers are 'required to adhere to' and to which they are required to refer when assessing applications for lease, permits or exemptions for activities. The Code refers to other relevant codes, key resources and databases to aid in the management of *P. cinnamomi*, which is regarded as one of the primary plant disease problems in Tasmanian reserves (TPWS, FT & DPIWE, 2003).

Cruisin' Without Bruisin' is a track guide and Code of Practice that was developed for recreational vehicle users in parks and reserves of Tasmania. The Code is published on the TPWS website (TPWS website – 4WD Recreation, accessed 18/02/05) and is also available in pamphlet form. This guide describes how *P. cinnamomi* is readily spread in soil, recommends starting trips with a clean vehicle and equipment, and where possible in dry conditions. The website version refers the reader to other web pages with more detailed information on *P. cinnamomi*. Guidelines for teachers and instructors taking students to infested National Parks is available on the Tasmanian Department of Education website (TDE website – Phytophthora Root Rot, accessed 01/03/05) with links to the more detailed information provided on Tasmanian Department of Primary Industries, Water and Environment (DPIWE) and TPWS websites.

Other documents which may embody the policy of an organisation and provide operational guidance to the management of *P. cinnamomi* include standard operating procedures or operational guidelines. They will be discussed in more detail in a later section, Section 3.6 Standard Operating Procedures.

Gaps in Current Non-Statutory Policy and Planning

As for statutory policy, the major gap in terms of non-statutory policy and planning is the absence of a whole-of-government approach to the management of *P. cinnamomi* within the States. Without a coordinated approach it will be impossible to develop consistency between the States, which would provide for a common understanding of the impact of the pathogen on Australia's biodiversity, and mechanisms for technology transfer and adoption of best practice management techniques.

Clear policy is needed throughout Australia at all levels of government and at the corporate level within all land management agencies. The slow uptake of dieback policy by Local Government in Perth is attributed to a lack of clear direction and guidelines from the WA State Government to date (McCarthy, 2005a). Existing policies on *P. cinnamomi* management in Australia apply to lands of specific and limited tenure, usually conservation estate. The WA DWG Group and the SA *Phytophthora* Technical Group have attempted to provide guidance and direction to the managers of lands outside the conservation estate. The WA DWG was funded through a series of competitive Australian Government grants, which have now lapsed leaving the Group in extreme financial uncertainty. The majority of SA *Phytophthora* Technical Group members are voluntary and their actions are limited by a lack of funds.

A major gap in planning for *P. cinnamomi* management is an appropriate trigger to ensure that containment measures and protection of biodiversity from *P. cinnamomi* are included in the management planning process. Many States/Territories have such triggers for the consideration of weeds and fire but not for *P. cinnamomi* (I Smith, *pers. comm.*).

P. cinnamomi has been formally acknowledged as a key threatening process to natural ecosystems in NSW and is heavily implicated in the disease syndrome occurring in the wet tropics of North Queensland. However, the land management agencies in NSW and Queensland currently have no policies governing the management of *P. cinnamomi*, which may inadvertently lead to further spread *P. cinnamomi* in the landscape and degradation due to the disease it causes.

Although implementation of hygiene protocols such as those outlined in Worboys and Gadek (2004) can be made a condition of a Wet Tropics Permit, enforcement can be problematic due to poor understanding of *P. cinnamomi*. This is being addressed through the education of bushwalkers and limited on-ground training of QPWS staff.

A whole-of-government approach to *P. cinnamomi* management will require collaboration between all arms of government, as well as coordinated partnerships with industry and the community. Before this occurs, the lack of basic knowledge about the pathogen and its impact within government and amongst the general public will have to be addressed.

3.1.3 *Investment*

Investment refers to the commitment of resources to all aspects of *P. cinnamomi* management including research. The Australian Government has invested considerable amounts of funding through programs such as Australian Research Council (ARC), the first round of Natural Heritage Trust (The Trust) funding, National Action Plan for Salinity and Water Quality (NAPSWQ), World Heritage funding and core funding for Threat Abatement Plans. These programs have yielded many benefits to the science, management and general awareness of *P. cinnamomi* in natural ecosystems. However, the *ad hoc* and short-term nature of the available funding precludes a strategic long-term approach to research and management necessary to i) determine the full extent of *P. cinnamomi* and its impact in Australia and ii) effectively abate the threat of the pathogen.

The investment by State and Local Governments in *P. cinnamomi* science and management varies from State to Sate but is generally very low. Relatively modest investments by the WA and South Australian (SA) State Governments in appointing personnel with specific *P. cinnamomi* management roles has led to greater coordination of activities in those States, although funds for on-ground management funds are limited.

It is widely recognised that *P. cinnamomi* is but one of the many competing demands on the limited funding available for management of serious environmental issues in Australia. The core Australian Government funding for the eight approved Threat Abatement Plans is currently inadequate and the demands on the available funding is set to increase as new Key Threatening Processes are listed. National and State priorities need to be set to ensure that funding is directed where it is most needed and where it is likely to provide the greatest return. Secure alternative funding sources must be found.

Access to the Trust and NAPSWQ funds through the Natural Resource Management (NRM) regions for *P. cinnamomi* research and management will depend on the priorities of the individual regions as identified in their strategic and investment plans. However, it remains to be seen how this regional delivery model will impact in the management of a national threat such as *P. cinnamomi*.

Current Practice in Investment

It is crucial that all organisations responsible for *P. cinnamomi* management commit to and provide adequate and appropriate resources for the implementation of policies and plans. Early funding arising from the NTAP was directed at on-ground projects, but in the last two years more strategic national funding has been directed to the objectives of the Plan. Projects arising from the NTAP are funded through the Natural Heritage Trust.

In July 2005, DEH allocated approximately $2M from Threat Abatement Plan funding to Deakin University in Victoria and the Centre for *Phytophthora* Science and Management (CPSM) at Murdoch University in WA, for the following projects:

- Develop methods to exploit the mechanisms of natural resistance to *P. cinnamomi*
- Enhancing the efficacy of phosphite with the addition/supplementation of other chemicals
- To determine if the physiological status of the plant at the time of the spraying affects the efficacy of phosphite?
- Eradication of *P. cinnamomi* from spot infection in a native plant community in WA
- Eradication of *P. cinnamomi* from spot infection in a native plant community in Tasmania.

An economic analysis of the impacts of *P. cinnamomi* was identified as one of nine areas that require urgent attention to effectively address the threat of *P. cinnamomi* in WA (WWF and DCC, 2004). As part of the Dieback Response Framework in WA, a business case study has been commissioned to quantify the benefits of investing in the amelioration of the threat, and conversely the risks of failing to invest or delaying investment (Economic Research Associates, 2005). The Business Case Study will form the basis of a case for long-term and strategic investment to be put to the WA Government, Industry and the Community.

It is difficult to get a clear picture of current level of commitment to *P. cinnamomi* management from the amount of funds spent on on-ground management, as these costs are commonly not identified within District operational budgets (D Peters and T Rudman, *pers. comm.*) and may require external funding (R Velzeboer, *pers. comm.*). CALM invest approximately $1.5M per annum in *P. cinnamomi* management, which includes a fulltime Coordinator and Senior Research Scientist positions. It does not include mapping, planning or the application of hygiene prescriptions for all key operations. These costs, which may amount to several million dollars per annum, are absorbed by the section of the department responsible for those activities; mining companies and major utilities, as a necessary part of their environmental management during operations (K Vear, *pers. comm.*).

The threat *P. cinnamomi* poses to biodiversity is acknowledged in some States by an investment in human resources, particularly the funding of positions with dedicated responsibilities for the coordination of *P. cinnamomi* management. As the result of recommendations in a 1996 review of *P. cinnamomi* management in WA (Podger *et al.,* 1996), CALM re-established the full-time position of *Phytophthora* Management Coordinator. This key position has responsibility for the coordination of the *P. cinnamomi* management activities within CALM, from the development of departmental policy, strategies and plans to the deployment of on-ground management, training and communications (CALM, 2003). The *Phytophthora* Management Coordinator is also commissioned with the facilitation of management activities by other agencies, and the promotion of close collaboration between research scientists and land managers (Podger *et al.,* 1996), which includes membership of the WA DWG Management Committee (Zuvela, 2002).

The *Phytophthora* Management Coordinator in CALM is supported by a number other positions with responsibilities for varying aspects of *P. cinnamomi* issues relating primarily to the Department's forestry operations including; District Phytophthora Management Coordinator, Disease Standards Officer, Senior Interpreter and Phosphite Officer (CALM, 2003). The clear definition of roles and responsibilities of staff in relation to *P. cinnamomi*, in conjunction with appropriate training, is crucial to the implementation of best practice management. CALM have clearly stated the roles and responsibilities for each position in the departmental management guidelines, which are also available to the public from the CALM website (CALM, 2003).

There is no other State in Australia with a full-time position dedicated to *P. cinnamomi* management. However, South Australian Department for Environment and Heritage (SA DEH) and the Tasmania's DPIWE each have a position with fractional responsibilities for *P. cinnamomi*. The position of Ecologist–Plant Dieback in SA had fulltime responsibilities for *P. cinnamomi* issues from 2000-2004, while funded under the Trust and the NAPSWQ. Since funding for the position has been assumed by SA DEH the responsibilities have been broadened to include other dieback issues, so that only 50% of the position is currently apportioned to the coordination of *P. cinnamomi* management in the State.

The Trust and the NAPSWQ have been an important source of funding for key initiatives in *P. cinnamomi* management in Australia. Some of the most successful initiatives have been those that provided for human resources, such as the example discussed above where a dedicated position was funded in SA for 4 years. The position of Dieback Project Officer with the WA DWG was funded from 1998 to 2004 through 3 separate Trust grants. This position was deemed necessary and has proven crucial in; identifying and overcoming barriers to the acceptance and uptake of policies for *P. cinnamomi* by Local Government, and raising awareness of *P. cinnamomi* in the general public of the South West of WA (Lewis *et al.,* 2000; Zuvela, 2002).

Mechanisms for the delivery of $3 billion (Trust) and $1.4 billion (NAPSWQ) funding have changed in recent years, to a model in which integrated delivery of the two funds is driven by strategic and investment plans developed by the 56 individual NRM Regions that cover Australia (NRM website – About NRM Regions, accessed 05/07/05). It remains to be seen how *P. cinnamomi* management activities funded under the original Trust system will fare under the new system.

The strategic and long-term investment of resources by Alcoa World Alumina (Alcoa), have resulted in significant advances in *P. cinnamomi* management in high-risk situations. Alcoa has been mining bauxite in the WA jarrah (*Eucalyptus marginata*) forest since 1963, and managing the risks associated with the presence of *P. cinnamomi* has been a major challenge (Colquhoun and Hardy, 2000). One of Alcoa's major environmental objectives is to minimise the spread of *P. cinnamomi*, which has been driven by an intensive research and development program within the company and in conjunction with Murdoch University (Colquhoun and Hardy, 2000).

The cost of implementing *P. cinnamomi* management procedures in a mining process in jarrah forest that is 85% disease-free, was estimated at US$1.5M/year (Colquhoun and Hardy, 2000). Most of the costs are indirect and result from inefficiencies in operations caused by *P. cinnamomi* management prescriptions (Colquhoun and Hardy, 2000), although there is a significant investment in human resources to lead the research and development program, and to implement, monitor and audit the on-ground procedures (I Colquhoun, *pers. comm.*).

Many of the positive outcomes identified as current best practice in this document, can be attributed directly to the allocation of human resources to coordination, which has resulted in a concerted and consistent approach to *P. cinnamomi* management to be developed and promoted. Something much less tangible and impossible to prescribe for, but which was apparent from this review, is the high calibre and personal commitment of many of the people either employed, or voluntarily engaged in *P. cinnamomi* management in Australia.

The Australian Government is a major contributor to research on *P. cinnamomi* in natural ecosystems also through the Australian Research Council (ARC). From 1998 to 2004 Murdoch University in WA received $3M in funding largely through the competitive grant processes of the ARC (Hardy *et al.,* 2002). The mining industry has also made a significant contribution to research in WA (Hardy *et al.,* 2002). Since 1993, Alcoa has had a collaborative relationship in research with Murdoch University (Hardy and Colquhoun, 2000). Alcoa has constructed a joint laboratory facility and glasshouse at Murdoch University, and contributed to studies on; the effect of conditions in rehabilitated mine sites on infection and disease, the effect of phosphite on target and non-target organisms, as well as epidemiological studies. Alcoa provided crucial support for the establishment of the CPSM at the University.

In the eastern States, the agricultural and horticultural industries have invested in *P. cinnamomi* research. A project spanning 1992-2004, to assemble a culture library, assess genetic diversity within species and develop a Polymerase Chain Reaction (PCR) based diagnostic test for *Phytophthora* species, which is now commercially available in kit form, received $1.3M in funds and in-kind contributions to the Cooperative Research Centre for Tropical Plant Protection (CRC TPP), it's predecessor and partner institutions (Agtrans Research, 2004). Funds for the project were obtained in a series of grants over the years from Rural Industries Research and Development Corporation, Horticultural Research and Development Corporation, Horticulture Australia Limited and the Australian Centre for International Agricultural Research (Agtrans Research, 2004).

Gaps in Investment

Funding is currently inadequate to effectively abate the threat of *P. cinnamomi* in Australian natural ecosystems, a view that has also been expressed in a number of previous reviews (Stretch *et al.,* 1992; Cahill, 1993; Podger *et al.,* 1996; WWF and DCC, 2004). It will not be possible to attain national best practice in *P. cinnamomi* management as per the model in Figure 2.1, without a strategic and sustained program of collaboration and coordinated investment from all levels of government, industry stakeholders and the community.

In terms of investments in *P. cinnamomi* management and research to date, the Australian Government has been a significant contributor of *ad hoc* funds, while the States, with the exception of WA, and have invested very little. CALM calculates that it spends approximately $1.5M per annum on direct *P. cinnamomi* management (K Vear, *pers. comm.*), and Alcoa estimates that it costs the company $1.5M to effectively manage *P. cinnamomi* in their mining operations (Colquhoun and Hardy, 2000). However, even this level of investment falls far short of the estimated $6.7 million needed in the first year and $4.1M thereafter for strategic, coordinated and collaborative programs of research, management and administration to effectively abate the threat of *P. cinnamomi* in the South-West of WA (WWF and DCC, 2004).

Inadequate and *ad hoc* investment in *P. cinnamomi* has an adverse effect on all levels of management from legislation and statutory policy to the availability and deployment of on-ground measures. The failure to invest adequately in *P. cinnamomi* has meant that the extent and impact of *P. cinnamomi* in natural vegetation in some States, particularly NSW and Queensland, has not been properly assessed. It is impossible to develop policy or plans for action in the absence of such basic information.

The importance of investing in dedicated personnel is recognised in WA, and a recent review has called for more resources to employ a technical officer in each of the key NRM Regions in the South-West of the State (WWF and DCC, 2004). This investment in human resources is seen as necessary for coordinated and consistent management of *P. cinnamomi* in WA and as a source of information and technical advice to the community and all levels of government (WWF and DCC, 2004).

Where States do not currently have dedicated *Phytophthora* personnel, a commitment to the funding of a central coordinating position would represent a modest investment with the potential to make significant gains, such as those realised by similar undertakings in WA and SA. As discussed in Section 3.6 Standard Operating Procedures, excellent guidelines have already been developed and are readily available, for planning through to deployment of management prescriptions. With these considerable management tools, a suitably qualified and experienced person in each State could develop, coordinate, promote and integrate the necessary management for local threat abatement, and provide expert input to policy development and planning.

While *ad hoc* funding of *P. cinnamomi* has led to significant achievements in management and research, there are major disadvantages to the current non-strategic approach to investment. The momentum of successful programs and experienced personnel are lost when funding lapses and other sources cannot be found. Additional dangers include the potential for inconsistent messages to be promoted and a generally fractured and uncoordinated approach to management. In many States suitably qualified staff are either part-time, temporary or not officially established in positions with *P. cinnamomi* management responsibilities. A sustained, intensive and strategic approach to investment in management and research is regarded as urgent (Hardy *et al.,* 2002; WWF and DCC, 2004).

It is acknowledged that resources to deal with *P. cinnamomi* will never be sufficient due to competing demands of other natural resource management issues, and that responsibility for effective management cannot be borne solely by governments (Podger *et al.,* 1996; Environment Australia, 2001; WWF and DCC, 2004). The establishment of a trust fund under legislation to receive contributions for research and the protection of areas of high conservation value, was recommended in two previous reviews of *P. cinnamomi* in WA (Stretch *et al.,* 1992; Podger *et al.,* 1996). Under these recommendations, funds would be derived through tax-deductible donations and levies imposed on all activities and land-users that have the potential to introduce or spread the pathogen on CALM lands (Stretch *et al.,* 1992; Podger *et al,.* 1996). To date, these recommendations have not been pursued in WA.

In order to justify, and get community endorsement for, an immediate and sustained investment by all stakeholders in threat abatement, a national cost/benefit analysis is urgently needed, which addresses the extent and impacts of *P. cinnamomi* disease in Australia, the projected costs of effective management, the risks of failing or delaying investment and a realistic investment strategy.

3.2 Research

Research refers to scientific investigation into all aspects of *P. cinnamomi*, the disease it causes, the consequences and management of the disease. World class research is undertaken throughout Australia ranging in scope from cellular and molecular biology of *Phytophthora* species through to directly applied research into on-ground management methods.

Despite a dynamic research culture in Australia, many gaps in fundamental knowledge about *P. cinnamomi* remain, and these gaps are a significant impediment to effective management. Research on the potential to restore infested and highly impacted sites has been minimal, despite continual growth in the number of such sites and the fact that once infested, *P. cinnamomi* cannot be eradicated. Although these gaps have been identified in numerous reviews over the years, the *ad hoc* funding of research, the lack of coordination between research groups to prevent duplication and to set priorities, precludes a long-term and strategic approach to addressing the gaps.

The fact that a large proportion of research in Australia is being undertaken by postgraduate students, and therefore designed for completion in a three-year time frame, has meant that many of the gaps that require long-term monitoring are not being undertaken.

Two initiatives in WA to address long-standing knowledge gaps include: i) the setting of research priorities for WA by the State Government Ministerial-appointed DCC, ii) the development of the Centre for *Phytophthora* Science and Management with a holistic and long-term vision for research on diseases caused by *Phytophthora* in natural ecosystems and collaborations with key stakeholder to ensure that research directly addresses on-ground management.

Current Practice in Research

Australia has a number of world-leaders in *Phytophthora* research. Table 2 summarises the scope of research currently being conducted in Australia by the various research institutions and government departments. *Phytophthora* research is carried out either in dedicated research facilities, Universities, or in a few cases, government departments. There are two key Centres in which *Phytophthora* research is conducted in Australia: the CPSM which focuses on research in natural ecosystems and the CRC TPP whose research on *Phytophthora* species is geared more toward agricultural and horticultural applications.

In June 2003, the CPSM was launched in WA by the State Minister for Environment. The Centre is based at Murdoch University, where research on *P. cinnamomi* in natural ecosystems has been conducted since 1986 covering the biology, ecology, genetics, pathology and control of *P. cinnamomi* in natural ecosystems, horticulture and in the rehabilitation of mine sites (Hardy *et al.,* 2002). The Centre is based on collaborations built over time with CALM, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Agriculture Western Australia and industry (Hardy *et al.,* 2002). The Centre also provides graduate and postgraduate training. The CPSM is seen as the focal point for *P. cinnamomi* research in WA, which is an essential part of the campaign by the WA State Government appointed DCC, to develop a holistic approach to managing the threat in the State (WWF and DCC, 2004).

The main objectives of *Phytophthora* research in the CRC TPP are: the development of a diagnostic test for industry, the identification of markers for resistance genes in *Phytophthora*, and the identification of avirulence/pathogenicity genes and elucidating their function (CRC TPP website, accessed 10/02/05). As a result of this research program a DNA based identification kit called Phytophthora-IDENTIKIT™ was commercially released in 2004, for use by PCR licensed laboratories. The kit can detect and identify 26 different *Phytophthora* species from plant material (CRC TPP website – *Phytophthora* – IDENTIKIT, accessed 10/02/05).

As discussed in Section 3.1.3 Investment, sourcing adequate funding for research on *P. cinnamomi* disease in natural ecosystems is a constant challenge. It is now recognised that a system for priority setting in management is essential for cost-effective and efficient use of limited resources, and similar processes need be applied to setting priorities for research.

Table 2 The scope of and institutions currently involved in *Phytophthora* research in Australia.

Institution	Research Theme
CRC Tropical Plant Protection	development and maintenance of a *Phytophthora* culture collection
CRC Tropical Plant Protection Centre for *Phytophthora* Science & Management	development of diagnostic tools
Australian National University CRC Tropical Plant Protection Deakin University	cellular and molecular biology of *P. cinnamomi*
Centre for *Phytophthora* Science & Management Department of Conservation & Land Management Deakin University University of Sydney	the use of phosphite to manage *Phytophthora* diseases
Deakin University Centre for *Phytophthora* Science & Management	the effects of *P. cinnamomi* on fauna
Centre for *Phytophthora* Science & Management	socio/economic effects of *Phytophthora* disease
Department of Conservation & Land Management Centre for *Phytophthora* Science & Management	epidemiological studies
Department of Conservation & Land Management Centre for *Phytophthora* Science & Management	investigation on susceptibility and resistance to *Phytophthora* in plant populations
Centre for *Phytophthora* Science & Management	fire/phosphite interactions
Department of Conservation & Land Management	*ex-situ* conservation of critically threatened plants
Wet Tropics Management Authority and James Cook University (occasional)	impacts and management of *P. cinnamomi* in tropical rainforests

The West Australian DCC was established, in part, to develop research strategies directed at the needs of planners and managers of operations (Podger *et al.,* 1996). A subcommittee was formed in 2003 to identify research topics to address current knowledge gaps about the pathogen, the disease it causes and its management in WA. From the 30 topics identified by the subcommittee, the DCC produced a short-list of prioritised research topics by applying a set of criteria based on: the likelihood of success of the project, speed to outcome, the direct applicability to management, affordability and contribution the research would make to protecting threatened biodiversity. Although the lists of research topics were developed specifically for WA, they could equally address many of the National gaps in knowledge about the pathogen and its management.

An Advisory Committee appointed by the Australian Government DEH in December, 2004 will assist in identifying projects of the National priority for funding under implementation of the NTAP.

Gaps in Research

Many of the gaps in current knowledge about *P. cinnamomi* and its management can be traced back to the inadequate and non-strategic approach to the funding of research in Australia including: an erosion of the research capacity of State Government Departments, significant gaps in our knowledge that have been repeatedly identified but never effectively addressed, and a lack of, or insufficient information about, the extent of the threat in some areas of Australia to support an effective management response.

In the seven years from 1998 to 2004 *Phytophthora* research at Murdoch University, at what is now the CPSM, received $4.5M in cash and in-kind funds from government and industry (Hardy *et al.,* 2002). However, it is estimated that $3M per year is required to effectively address the gaps in our current knowledge that would enable effective management of the pathogen (WWF and DCC, 2004).

Over the years there has been an erosion of research capacity in State Government Departments, with only a one remaining senior research scientist engaged in fulltime research on *Phytophthora* diseases in natural ecosystems in Australia. The operating budget for the Senior Research Scientist at CALM for 2005 is $5,000 (B Shearer, *pers. comm.*), although there is a range of research being undertaken in other CALM programs with direct benefits for *P. cinnamomi* management such as phosphite research and programs on *ex-situ* conservation and translocation.

A number of past reviews have identified critical gaps in knowledge about *P. cinnamomi* and the disease it causes in natural ecosystems (Shearer and Tippett, 1989; Stretch *et al.,* 1992; Cahill, 1993; Podger *et al.,* 1996; Cahill *et al.,* 2002). The most recent compilation of research needs was commissioned in WA by the DCC in 2003. The gaps identified have the potential to significantly hamper management efforts. There has been a number of recurring themes in past reviews including the:

- incomplete knowledge of the epidemiology of *P. cinnamomi* in Australia
- incomplete knowledge of the vulnerability of Australian flora and fauna to the impacts of *P. cinnamomi*, particularly of threatened species and communities
- inability to accurately determine the presence or absence of pathogen in the landscape
- unknown effectiveness of current methods of management
- incomplete knowledge of the target and non-target effects of phosphite
- failure to exploit natural resistance as a tool in management
- unknown implications of climate change on disease impact and spread.

Increasing concerns about the ability to effectively protect uninfested areas from autonomous spread of *P. cinnamomi* has prompted renewed calls for research into methods for the eradication of localised incursions. Given the distribution of the pathogen in the landscapes and the mechanisms of autonomous spread e.g. motile zoospores, surface and subsurface drainage and root to root contact, the approaches to investigate eradication methods are likely to be radical.

In WA, the Fitzgerald River National Park has sparked the call for urgent research into eradication methods. The current disease front of the Bell Track has nearly reached the watershed boundary of a poorly defined, internally draining micro-catchment, and if it spreads to the two adjoining drainage lines a rapid and unchecked spread is predicted with catastrophic consequences for highly diverse, highly endemic flora and the habitat of a number of endangered and critically endangered fauna (M Grant, *pers. comm.*). In the case of Tasmania, the call is pre-emptive; so that eradication methods are available should there be an incursion in some of the currently disease-free pockets and islands of the State (T Rudman, *pers. comm.*).

Many more fundamental questions remain unanswered in other parts of Australia, such as the role of *P. cinnamomi* and other *Phytophthora* species in the disease syndrome occurring in high altitude (>750m) rainforests of the Wet Tropics World Heritage Area. These forests contain high floral endemicity, and particularly on high mountaintops a number of species with extremely restricted distributions. Many of these species belong to taxonomic groups with Gondwanan affinities (e.g. Epacridaceae and Proteaceae) known to contain susceptible taxa. The highland forests typically have comparatively high mean temperatures, very high, year round rainfall, and heavily leached acidic soils. Research questions which have yet to be addressed include controlled assessments of the susceptibility of rainforest taxa, the genetic diversity of *P. cinnamomi* within the Wet Tropics, the interaction of *P. cinnamomi* with other (pathogenic) *Phytophthora* species present in soils of the region, and the likelihood of non-anthropogenic spread within the area.

The restoration of infected and high impact sites is an area that has received very little attention in the history of *P. cinnamomi* research in Australia. Alcoa has a research program. Under the agreements of the mining lease in the jarrah forest of WA, Alcoa and CALM have a program to treat dieback affected jarrah forest. The areas rehabilitated are not suitable for mining but occur within the bauxite mining lease (Anon, 1996). Alcoa invests approximately $300,000 per year in the program in which 50-100ha of disease affected jarrah forest are rehabilitated with a focus on biodiversity values (I Colquhoun, *pers. comm.*).

One of the major objectives of the NTAP is to improve the effectiveness and efficiency of the management of *P. cinnamomi* through appropriate research and monitoring programs. The actions included the establishment of monitoring sites to determine long-term direct and indirect impacts of *P. cinnamomi* on biodiversity and the effectiveness of current management methods. If implemented, these actions would have addressed a range of the long-standing knowledge gaps that are currently hampering effective management.

Most research is now undertaken in research institutions or universities, and is carried out predominantly with *ad hoc* funding by postgraduate students at Honours or Doctorate level. The high incidence of research being undertaken by postgraduate students is probably the main reason why many of the more difficult questions remain unanswered. In the interest of the candidate, student research projects must be designed for completion within three years (nine months for Honours students) and have good prospects for successful outcomes. To adequately address many of the gaps in current knowledge, a strategic program with sustained funding is required by experienced research scientists, with assistance from high calibre postgraduate students.

3.3 Training and Extension

Training refers to the development and delivery of technical information that promotes skilled and effective participation in the management of *P. cinnamomi*, in accordance with standard operating procedures. Formal training for management of *P. cinnamomi* in natural ecosystems of Australia is not available in all States and there are no national standards for curricula.

Training is generally delivered on an *ad hoc* basis by State Government land management agencies. In WA, curricula are well developed by CALM in four competency-based courses ranging from strategic to on-ground management, and by Alcoa World Alumina Australia (Alcoa) in a computer-based learning system. Training is compulsory for Alcoa staff and must be refreshed biannually. Only the detection, diagnosis and mapping course is compulsory for staff and contractors of CALM with 'disease interpretation' responsibilities. The WA DWG provides training, consistent with the CALM curricula, to Local Government and other stakeholders. However, the capacity of the group to provide training where it is needed is limited due to inadequate and insecure funding.

Extension refers to the communication of the latest knowledge of *P. cinnamomi* and its management to all stakeholders. In Australia, the level of awareness and understanding of *P. cinnamomi* and its impact on biodiversity, at all levels of government and the community, is inadequate to effectively abate the threat. Poor policy/planning by governments and public opposition to various on-ground management tactics, are just two of the consequences of poor knowledge that significantly hamper management. A State Communication Strategy is currently being developed by the WA DWG and other stakeholders, to develop a consistent message and provide recommendations to each stakeholder group on behaviours necessary to manage *P. cinnamomi* and its impacts in WA. A national communication strategy is needed and is listed as a priority action of the 2001 NTAP, but is yet to be developed.

Extension is undertaken primarily by Government, with the exception in WA where the DWG has worked with Local Government, industry and the community to increase awareness and knowledge of the threat. Extension efforts are more comprehensive in WA (CALM and DWG) and SA (SA DEH) where dedicated personnel coordinate *P. cinnamomi* management activities within and between agencies.

Current Practice in Training and Extension

CALM developed and deliver four training courses to staff and contractors that are accredited within the organisation and the qualifications widely recognised in WA:

- *Phytophthora cinnamomi* management
- *Phytophthora cinnamomi* detection, diagnosis and mapping
- *Phytophthora cinnamomi* field operators' course
- *Phytophthora cinnamomi* phosphite operators' course.

The competency-based training is consistent with the detailed manuals that have been developed for management (CALM, 1999a; 2001 and 2003). CALM provides training to staff and contractors on a needs basis in the areas of *P. cinnamomi* management, field operations and phosphite operations, while training in detection, diagnosis and mapping is mandatory for Departmental 'Disease Interpreters'. As well as formal classroom training (four days), the detection, diagnosis and mapping course has a field experience requirement, of up to three months, before a trainee is considered qualified.

CALM policy on the management of *P. cinnamomi* in WA states that a 'qualified Disease Interpreter' must identify uninfested areas that are 'protectable' (CALM, 2004b). The current Forest Management Plan states that it requires the Department to identify skills, including disease mapping, and take steps to maintain the competency in those skills (McNamara, 2004).

Until recently, CALM and WA DWG were Registered Training Organisations which meant that the qualifications issued as part of their training programs were nationally recognised in accordance with the Australian Quality Training Framework.

The WA DWG and the SA DEH deliver training to a wide range of stakeholders including: government, non-government, industry, students (primary to tertiary) and community conservation and other interest groups. The WA DWG has reported that the greatest uptake of management recommendations comes from succinct messages that are well illustrated with photographs and diagrams, tailored to specific audiences, and where relevant, to the specific site being managed (C Dunne, *pers. comm.*).

Alcoa World Alumina Australia (Alcoa) conducts its own training of staff through a computer based Learning Management System, with a *P. cinnamomi* package, developed by the Company's Senior Environmental Consultant. The package consists of information about the biology and ecology of the pathogen, procedures for management in the Company's bauxite mines in WA and a self-test process. The test must be repeated until all questions are answered correctly, at which time an electronic report is automatically generated and sent to a designated Senior Environmental Officer. It is the responsibility of the Senior Environmental Officer to monitor the records and ensure all staff up-to-date with training. Office-based personnel are inducted through the system and given a computer-generated reminder to refresh their training every two years. Field-based personnel receive similar training but in a classroom setting, which is coordinated by the Senior Environmental Officer at the mine (I Colquhoun, *pers. comm.*).

With the growing realisation that *P. cinnamomi* is a national issue and the responsibility of the whole community, cooperation and collaboration between key stakeholders is viewed as crucial for effective management. A number of groups with a wide stakeholder membership have been formed in Australia to facilitate a coordinated approach to management at either a National, State or local area level (Table 3).

Although a series of public education campaigns have been run in WA since *P. cinnamomi* was identified as the cause of 'jarrah dieback' in 1965, there are still many misconceptions and generally poor knowledge of the issue in the State. To raise awareness and priority of *P. cinnamomi,* and increase ownership and action of the issue by the whole community, WA DWG and a sub-committee of the DCC have developed a communication strategy for WA. The Plan aims to eliminate current misconceptions and develop simple messages to encourage necessary behavioural changes for threat abatement in each stakeholder group (DCC and DWG, 2004).

Extension material has been developed to some degree in most States and includes printed and electronic media, signage and community events such as field days. In Queensland and NSW, brochures have been developed very recently and are directed primarily at visitors to specific vulnerable areas (NSW NPWS, 2004; SHFT, 2004; WTMA, 2004). The WTMA publication (WTMA, 2004) has been produced on a pocket-sized fold-out brochure, a simple innovation which makes the information convenient to carry and access when needed in the field.

Table 3 Groups in Australia with wide stakeholder membership, formed at a National or State level to coordinate management of *Phytophthora* diseases.

State	Name	Function
National	*Phytophthora cinnamomi* Advisory Committee	Provide advice to DEH on implementation of the NTAP
WA	Dieback Consultative Council	Appointed by State Government to provide expert advice to State Minister
WA	Dieback Response Group	Appointed by State Government to provide expert advice to State Minister. Implementation of the WA Dieback Response Framework (WWF and DCC, 2004)
WA	Dieback Working Group	Increase awareness of the issue, develop and prompt uptake of policy and management recommendations at a whole-of-community level (WWF and DCC, 2004; DCC and DWG, 2004)
WA	Dieback Information Group	Networking of stakeholders (C Dunne, *pers. comm.*)
SA	Phytophthora Technical Group	Communication and the promotion of 'whole-of-government' management in SA (PTG, 2003)
Victoria	Dieback Steering Committee	Provide guidance to DSE in the development of the Victorian Strategic Plan (DSE, 2004)

Since 2000 a coordinated message on *P. cinnamomi* management has been developed and delivered to the community in SA, facilitated by the Trust funding, and consistent with the standard operating procedures and guidelines developed for land managers (Section 3.6 Standard Operating Procedures). A range of fact sheets provide simple and clear guidelines for bushwalkers, horse riders, plant propagators and the general public (SA DEH website, Biodiversity/Plants and Animals, accessed 01/03/05). In 2004, two publications were released, one on *P. cinnamomi* specifically (SA DEH, 2004a) and the other on various forms of plant dieback with an accompanying diagnostic chart (SA DEH, 2004b). These publications are characterised by practical information on the pathogens, the diseases and their management with the use of clear and simple language and liberally illustrated with detailed photographs and diagrams.

The electronic media, particularly the internet is becoming an increasingly popular and powerful extension tool. The leading land management agencies in WA, SA and Tasmania have provided detailed information on *P. cinnamomi* on their websites, with most management documents, guidelines and brochures made available for download. Three research institutions, the CPSM in WA (CPSM website accessed 01/03/05), the NSW Botanic Gardens Trust (Royal Botanic Gardens Trust website, accessed 01/03/05) and the CRC for Tropical Rainforest Ecology and Management (CRC TREM website, accessed 12/08/05) publish information and research reports on the internet. A website that functions as a portal to all relevant information about *P. cinnamomi* and its management in WA is currently being developed as part of the communication strategy (DCC and DWG, 2004).

Figure 3.1 Gilbert the potoroo, developed by the West Australian Dieback Working Group to promote awareness about *Phytophthora cinnamomi* and its impacts in the South-West of Western Australia.

The communications strategy in WA also plans to make use of the more traditional forms of electronic media of radio and television through community announcements, and informative segments on relevant local gardening and environmental programs. A segment on *Phytophthora* diseases in gardens appeared in May, 2005 on the Australian Broadcasting Commission's national Gardening Australia program featuring the CPSM and the WA DWG.

The 'branding' of *P. cinnamomi* is another key strategy of the WA communications plan (DCC and DWG, 2004). In 2004, the WA DWG created a cartoon character called 'Gilbert' (Figure 3.1) the potoroo (*Potorus gilbertii*), based on Australia's most endangered marsupial whose habitat is under direct threat from *P. cinnamomi* (WWF and DCC, 2004). Gilbert will be featured on printed material, websites, in educational programs and on qualifying *P. cinnamomi*-free nursery products (WWF and DCC, 2004).

A new slogan of "Stop the Biological Bulldozer", which describes the impact of *Phytophthora* in WA, was launched in 2004, with the publication of a booklet which is generously illustrated with diagrams and beautiful colour photographs of threatened plants and animals (WWF and DCC, 2004). An increasing awareness of the real and potential impact of *P. cinnamomi* on fauna has resulted in the conscious decision in WA to use images of threatened mammals and birds to elicit community action.

There is still a perception in a large proportion of the WA community that *P. cinnamomi* affects jarrah exclusively, harkening back to the period when the disease was called 'jarrah dieback'. The WA DCC and WA DWG are working to dispel this misconception, while building on the communities existing knowledge of 'dieback' as an environmental problem. Consequently they have introduced and are promoting the more precise and inclusive term 'Phytophthora dieback' to describe disease caused by *P. cinnamomi* in natural ecosystems (DCC and DWG, 2004).

Gaps in Training and Extension

Training in all aspects of *P. cinnamomi* management is currently inadequate in Australia. With the notable exception of Western Australia, formal training in the management of *P. cinnamomi* is generally *ad hoc* or non-existent in most states. Although CALM and the WA DWG deliver a consistent message in their training, there is a need for a nationally agreed curriculum and means by which to deliver the training in all States. Consequently, the skills and knowledge required to effectively identify, manage and administer for *P. cinnamomi* disease in natural environments is lacking or deficient. The poor level of knowledge and training has negative implications for all levels of management - from the development of effective policy, the development and adoption of Codes of Practice, the deployment of on-ground prescriptions, through to community attitudes to management.

The training developed and delivered by CALM in WA is largely limited to staff and contractors. The WA DWG has provided training to other stakeholders including: Local Government, industry and the community. However, neither organisation was able to maintain the onerous administration involved in maintaining accreditation. The WA DWG are currently investigating the adoption of a *P. cinnamomi* training course by a registered training organisation, such a college of Technical and Further Education, where it can be integrated into other programs of relevance such as conservation and land management (C Dunne, *pers. comm.*). Training in *P. cinnamomi* management is still very much issue-based and needs to be integrated into other relevant training programs. Maintaining the impetus for stringent implementation of *P. cinnamomi* management tactics in the bauxite mines of WA has been identified as a significant challenge by Alcoa (Colquhoun and Hardy, 2000).

In WA, the transfer of technology and considerable expertise in the management of *P. cinnamomi* from scientists, consultants and CALM to other stakeholders, particularly Local Government, is perceived to be poor. Management of *P. cinnamomi* is not incorporated in any of the current training for Local Government Engineers and Planners and is therefore not considered an issue that needs to be addressed as part of core business (McCarthy, 2005a). The current review shows this lack of integration of *P. cinnamomi* with other environmental issues is a significant gap for all organisations and in all States where the pathogen requires management.

In contrast to the largely invisible *P. cinnamomi*, conspicuous environmental problems receive substantially more public attention. Salinity has become a significant component of school and undergraduate university syllabi in Australia due to the development of tailored resources, strategies and programs by government and the CRC for Plant Based Management of Dryland Salinity (Robey, 2001; DET & ACC, 2004; CRC PBMDS website, accessed 20/02/05). Although schools are identified as a key community stakeholders in WA (DCC and DWG, 2004) no such educational resources have been developed for *P. cinnamomi* in Australia.

Training and extension programs for land managers and the community are a priority of the NTAP (Environment Australia, 2001). Since the release of the NTAP in 2001, two projects on education and extension, one in Tasmania and one in SA, have been funded through the Plan.

The momentum for *P. cinnamomi* research and management decreased for a period in the 1980's and 1990's. However, in WA a number of key initiatives and collaboration between State and Local Governments, community organisations and researchers have led to a refocusing of efforts and movement towards a whole-of-community approach to management. While regained momentum is encouraging, *P. cinnamomi* cannot be eradicated once introduced to a site, and protection of vulnerable natural assets from the threat requires sustained action and commitment to management. Sporadic bursts of activity, particularly in extension efforts, have occurred in other parts of Australia and generally coincide with the availability of *ad hoc* funding.

A communication strategy, similar to that developed for WA, is needed at a national level. The national communication strategy outlined in the NTAP has not yet been initiated. A communications strategy needs to raise general awareness of the extent, impact and management of *P. cinnamomi* in Australia, but must also address key issues such as regional variations in impact, inconsistent terminology and definitions. Positive messages are needed about what can be done to manage the pathogen to foster support and action from all stakeholders. While WA has settled on use of the term '*Phytophthora* dieback' other terms are commonly used in other parts of Australia to describe the disease including:

- cinnamon fungus
- dieback
- jarrah dieback
- *Phytophthora* root and collar rot
- rainforest dieback
- root-rot fungus.

3.4 Detection, Diagnosis and Mapping

Knowledge about the location of *P. cinnamomi* in the landscape is essential in setting management priorities and in the deployment of on-ground management tactics. However, the detection, diagnosis and mapping of *P. cinnamomi* is expensive and maps showing *P. cinnamomi* infestation boundaries have limited temporal currency due to continual spread of the pathogen. Maps of disease occurrence can be developed at a lower cost through interpretation of aerial photographs, but they do not have the same level of detail as those produced through on-ground survey. Additionally, where disease occurs in the understorey of vegetation with a dense emergent layer, as in Tasmania, aerial photography is of little use in disease detection.

There has been no systematic program to map the extent of *P. cinnamomi* infestations in Australia. The collection of such data, primarily by State Government departments and in WA also by the WA DWG, is largely opportunistic or on a case-by-case basis. There are no standards in Australia for the collection and storage of data related to *P. cinnamomi* occurrence. However, Tasmania have produced a very valuable and readily accessible management tool by gathering *P. cinnamomi* survey data from a number of agencies in a centrally located database Geo Temporal Species Point Observations Tasmania (GTSpot), which is connected to other databases including the floristic databases TASVEG and WHA Veg.

There are no standard methods for the detection, diagnosis and mapping of *P. cinnamomi* in Australia. Some aspects of the process would be very difficult to standardise. For example, the 'disease interpretation' process developed by CALM is not directly transferable to areas where disease is cryptic and there are very few reliable indicator species, such as areas of NSW and the Wet Tropics World Heritage Area in Queensland.

Laboratory methods to detect *P. cinnamomi* in soil, plant and water samples have not been standardised in Australia, although the techniques are well established and it should be a relatively easy process. Currently, morphological methods are used in a vast majority of diagnostic laboratories, although molecular methods are also available and are more sensitive and are faster. The cost of processing samples using morphological methods is high enough to preclude large numbers of samples being processed. However, molecular diagnostics are more expensive again so that it is not yet a commercially viable option. Prices for either method are unlikely to come down until sample throughput increases.

Current Practice in Detection, Diagnosis and Mapping

Human activities are the major vectors of *P. cinnamomi* in natural ecosystems of Australia. The deployment of appropriate prescriptions to manage further spread of *P. cinnamomi* in the landscape firstly requires knowledge of the location of the pathogen. Current practice in detecting *P. cinnamomi* is through the identification of visible symptoms of disease in vegetation, and confirmation of its presence through sampling and laboratory analysis of soil and diseased plant tissues.

In WA, CALM employ and train dedicated staff in the detection, diagnosis and mapping of *P. cinnamomi*. The process hinges on reliable disease expression in a suite of plant species and patterns of expression in infested areas. CALM undertake surveys and develop a range of map products to guide on-ground management of *P. cinnamomi* during forestry and mining operations in the jarrah forest. In recent years, the systematic disease interpretation process has been extended for use in the wider conservation estate. It is central to the identification of areas in WA deemed to be 'protectable' from *P. cinnamomi* in the medium to long-term and afforded priority management by CALM.

CALM's detection and diagnosis process is carried out by certified 'disease interpreters' (McNamara, 2004) who are trained in basic biology and epidemiology of the pathogen, interpretation of visible disease symptoms at ground level and demarcation of infestation boundaries, interpretation of symptoms from aerial photography, sampling, data management, report writing and the production of maps (CALM, 2004d). CALM has produced a detailed manual for all aspects of detection, diagnosis, demarcation and mapping of *P. cinnamomi* (CALM, 2001). CALM interpreters play an important role in the identification of 'protectable areas' in WA, which are afforded the highest priority in protection from *P. cinnamomi*. They must be able to judge whether areas are positioned in the landscape and are of sufficient size that *P. cinnamomi* will not autonomously engulf more than a significant remnant within 2-3 decades, and must take into account the location of the area in relation to its proximity to free public access.

Detection and diagnosis of disease caused by *P. cinnamomi* on lands managed by CALM and other lands for which CALM has conservation responsibilities, must be undertaken by qualified personnel according to CALM policy, following procedures in the official Departmental manual 'Interpreter's Guidelines for Detection, Diagnosis and Mapping' (CALM, 2001), and their work monitored by the Departmental Disease Standards Officer (CALM, 2004b; McNamara, 2004).

Alcoa contracts CALM to undertake detection, diagnosis and mapping of land leased in the jarrah forest for bauxite mining, to enable the company to develop *P. cinnamomi* management plans for their operations. A private contracting company, whose personnel have undergone CALM training, provides detection, diagnosis and mapping services to other agencies, Local Government, the WA DWG and the general community (Glevan Dieback Consultancy Services, 2000 and 2002; Kilgour, 1999).

There are over 40 species of plant in WA that are reliably susceptible to *P. cinnamomi*, which are referred to as 'indicator species' and are commonly used in the interpretation of disease (CALM, 2001). The interpretation of visible symptoms of disease relies heavily on the evidence produced by the chronology and pattern of death in indicator species, coupled with knowledge and information about environmental factors, site characteristics, and other potential causes for the death of susceptible species including fire, drought, abiotic or other biotic diseases (CALM, 2001).

Since 1986, CALM has been assessing disease from 230mm colour aerial photographs (1:4500 nominal scale). Given sufficient disease expression, trained personnel can make decisions about the disease status of an area from aerial photographs taken in autumn under shadowless conditions (full cloud cover). In autumn infected plants that have died after making a final effort to respond to summer drought breaking rains, have yellow to bright orange leaves and are readily detected via stereoscopic examination of aerial photographs. Site visits to view the symptoms and sample recently dead plants are used to verify the interpretation of aerial photographs (K Vear, *pers. comm*.; CALM website - Detection, Mapping & Hygiene Practices, accessed 03/03/05).

In Queensland, aerial photography is used to identify 'dieback' polygons, which are patches of apparent canopy death or thinning. These areas range from 1 to >10ha and are mapped onto a Geographical Information System (GIS) layer. Dieback polygons delineate locations in which smaller patches of dead and dying canopies can be detected (Gadek and Worboys, 2003). High resolution videography and digital image analysis are being used to examine and map the distribution of *P. cinnamomi* in open forests and heathlands at Anglesea in Victoria (Gibson *et al.,* 2002). Videography and other systems such as digital cameras have a number of advantages over conventional aerial photography including cost efficiency, ready availability of imagery for visual assessment and digital processing, digital recording format, and the ability to collect data in a number of spectral wave-bands (Coops *et al.,* 1998).

On-ground surveys are undertaken in WA when detection cannot be done by aerial photography (CALM website - Detection, Mapping & Hygiene Practices, accessed 03/03/05), or when small areas are being assessed (Kilgour, 2000b). On-ground detection involves walking an array of parallel lines through a landscape while interpreting the symptoms of disease and recording the position of symptoms on maps and via Global Positioning System (GPS) coordinates. This method provides the highest level of details and accuracy of information for planners and managers but due to high labour/time requirements it is more expensive than interpretation of disease from aerial photographs (Vear, 2004). Economies of scale can greatly reduce the cost, for example on-ground survey of single hectare can cost as much as $800, while >100ha costs an average of $25/ha using aerial photography (P Blankendaal, *pers. comm.*).

To assist on-ground management during forestry operations by CALM, the disease status of areas surveyed is visibly demarcated with standardised system of coloured flagging tapes or by painting blazes on tree trunks (CALM, 2001). Alcoa maintains demarcation during mining and rehabilitation using a range of visible, non-structural barriers such as signs, bunting, flagging tape and 'blazing' of tree trunks, pegs and cones (Alcoa Procedural Control Documents). The various visible signals alert staff and contractors to infestation boundaries and trigger access and hygiene procedures.

The mapping of disease occurrence is based on visible symptoms in the vegetation. However, when a plant becomes infected by *P. cinnamomi*, it takes some time for symptoms to develop, also there are a number of tolerant hosts of *P. cinnamomi* which the pathogen can infect and persist in without causing disease symptoms. Consequently, CALM applies buffers in demarcating boundaries of infested areas, or where the disease status is unknown. Minimum up-slope buffers in susceptible vegetation are 15m, while downslope buffers may be >100m. The final decision on the appropriate size of a buffer relies on the expert judgement of the 'interpreter' after consideration of the likely spread of the pathogen in relation to environmental conditions and disease expression (CALM, 2001).

P. cinnamomi 'occurrence' maps are produced from the data collected as part of the assessment and survey processes. Occurrence maps form the basis of the *P. cinnamomi* 'protectable areas' maps and the 'hygiene management' maps. It is not practical or economically feasible to map the entire boundary of disease in WA, as the pathogen is so widespread in the 17 million ha of remnant native vegetation in the South-West of the State. Additionally, the dynamic movement of the pathogen means that maps are considered completely out of date and unusable after 3 years and the area must be completely re-surveyed. Prior to the commencement of operations on CALM managed lands, such as forestry or mining, the *P. cinnamomi* boundary must be re-checked if the occurrence map is greater than 12 months old.

The diagnosis of *P. cinnamomi* as the causative agent of disease requires samples of soil and tissues from affected plants to be analysed in a laboratory by appropriately qualified personnel. Laboratories with the capacity to analyse samples for the presence of

Phytophthora species exist in most States and Territories (Part 3 – Risk Assessment for Threats to Ecosystems, Species and Communities: A Review). The majority of laboratories in Australia use conventional identification methods where the pathogen is isolated from soil, plant tissues or water samples, grown as pure cultures and identified to genus and species level by the morphological characteristics, primarily of the reproductive structure (Drenth *et al*., 1999; Drenth and Sendall, 2001).

In Western Australia, all *P. cinnamomi* survey data collected by CALM must be recorded in a format suitable for digitising. Maps and written summary reports must be incorporated into the Department's corporate database, which is maintained by the Forest Management Branch (McNamara, 2004). In South Australia, GPS datum, symptom and sampling results from the annual surveying program are recorded and maintained in the SA DEH database.

In Tasmania, a database called GTSpot administered by the DPIWE contains data submitted by DPIWE, Tasmanian Parks and Wildlife Service and Forestry Tasmanian relating to pathogen isolation records and symptom distribution. Pathogen isolation records, based on soil sampling since 1972 by Forestry Tasmania, do not indicate the extent of an infestation only that the pathogen was isolated from a particular spot. Symptom data distribution data consists of polygons assessed visually by trained observers. Polygon boundaries are arbitrary and generated on the extent of visible symptoms observed on the route taken. The database also contains maps of areas susceptible to *P. cinnamomi*, and *P. cinnamomi* management areas for Tasmania (DPIWE website – GTSpot User Guide, accessed 03/03/05).

Gaps in Detection, Diagnosis and Mapping

Maps that accurately depict the boundaries between infested and uninfested sites are essential to effectively limit the spread of *P. cinnamomi* and mitigate the impact of disease. However, only a small percentage of infestations have been mapped in Australia. The reason for this includes shifting commitment by agencies over the years to the management of *P. cinnamomi*. For example, in the 1970s and 1980s there were extensive surveying in Victoria for the presence and impact of *P. cinnamomi*, but since then very little has been done (I Smith, *pers. comm*.). There are also economic and practical impediments to the production and maintenance of strategic and operational maps of *P. cinnamomi* distribution.

Western Australia is the only State with formalised training in the detection, diagnosis and mapping of *P. cinnamomi*, and CALM are the only agency with a qualification requirement for personnel undertaking the task. The production of accurate *P. cinnamomi* maps in WA relies on the interpretation of visible symptoms of disease in a range of reliably susceptible plants known to be reliable indicator species. However, in Northern Queensland and in NSW, there is a lack of reliable indicator species, and symptom expression can be diffuse which renders the infestation boundary very difficult, if not impossible, to define (Gadek and Worboys, 2003). Even in the temperate south of the continent where there are reliable indicator species, visible symptoms of disease can be masked by drought or destroyed by fire, both of which are expected to increase in frequency according to the predictions of the CSIRO climate-change models for Australia (CSIRO, 2001).

Detailed mapping of *P. cinnamomi* has been undertaken to a very limited extent in Tasmania, as resources are lacking (including trained personnel) to undertake the task in the often rough and remote terrain where on-ground surveys are labour intensive and expensive. The few detailed maps produced rely on the extent of visible infestation observed during ground survey, and polygons may be arbitrary (T Rudman, *pers. comm.*). State maps have been created of the broad scale distribution of *P. cinnamomi* from spot isolation data (Podger, 1999), and spot and polygon symptom data (T Rudman, *pers. comm.*).

Interpretation of aerial photographs for mapping disease boundaries is generally not suitable in Tasmania where there is a lack of susceptible species in the dense emergent shrub or forest layer, and the scale of photography (1:25,000) precludes interpretation of disease symptoms (T Rudman, *pers. comm.*). Aerial photography at 1:5,000, if available, would be useful in grasstree dominated communities (T Rudman, *pers. comm.*). Maps produced from the interpretation of aerial photographs do not have the same level of accuracy or detail as those produced through on-ground surveys (Vear, 2004).

The autonomous movement and spread of the pathogen by uncontrolled vectors means that *P. cinnamomi* distribution maps have a limited currency of 1-3 years. However, as alluded to above, the costs of on-ground survey and sample analysis makes the initial mapping or updating of maps prohibitively expensive.

Laboratory analysis of plant tissue and soil samples can confirm the presence of *P. cinnamomi* at a site, and can assist in determining the boundary of an infestation as plants at the disease front will be asymptomatic for some time after infection occurs. However, sampling is currently used to confirm the presence of *P. cinnamomi* at a site, but it is not economically feasible or practical to use sampling to map where visible clues of disease are absent.

The presence of *P. cinnamomi* at a site can be confirmed from a single positive sample, but a site cannot be deemed free of the pathogen from a single negative sample. A systematic survey of long infested sites in WA determined that the number of samples needed to be analysed and return a negative result to pronounce a site free of *P. cinnamomi* with 95% confidence, is 271 (Davison and Tay, 2003). This level of sampling would cost $23,848 at an average of $88 per sample for analysis (Part 3 – Risk Assessment for Threats to Ecosystems, Species and Communities: A Review), and would be economically unfeasible in most circumstances. These results cannot be extrapolated to other parts of Australia. In the wet tropics of Northern Queensland, *P. cinnamomi* was shown to be uniformly distributed in the landscape and it was estimated that a minimum of 2-4 soil samples were required per 1256m^2 to predict the absence of *P. cinnamomi* with 95% confidence (Pryce *et al.,* 2001).

The vast majority of laboratories offering *Phytophthora* diagnostic services use conventional techniques of baiting, plating and identification to genus or species level through assessment of morphological characteristics. Diagnostic services for *Phytophthora* are often poorly advertised and it was surprisingly difficult to get specific information from a number of laboratories despite direct and repeated enquiries. Only one laboratory in Australia is currently accredited under the National Association of Testing Authorities (NATA website, accessed 20/05/05) for *Phytophthora* and *Pythium* diagnostics. The throughput of samples is very low in many laboratories and will be an impediment to reducing the cost of the service. For example, the Forestry Tasmania laboratory processed an average of 65 soil baits/year for the last 5 years (T Wardlaw, *pers. comm.*), and in 2003 there were approximately 80 requests for *Phytophthora* testing at the Plant Disease Diagnostic Unit of The Royal Botanic Gardens of Sydney (Royal Botanic Gardens and Domain Trust, 2003).

Individual organisations and some commercial laboratories provide instructions on collection and storage of samples (NPS, 1994; CALM, 2001; Drenth and Sendall, 2001; Pryce *et al.,* 2001; Rudman, 2004). Drenth and Sendall (2001) have produced an excellent guide to the isolation and morphological characterisation of *Phytophthora.* However, this is an internal publication of the CRC TPP and is not widely available. There are no national standard protocols for sampling methods, frequency, isolation or identification of *Phytophthora* in Australia, and descriptions of sampling methods and scale are generally poorly reported in the scientific literature (Pryce *et al*., 2001).

The European and Mediterranean Plant Protection Organisation (EPPO) is an intergovernmental organisation responsible for cooperation in plant protection in the European and Mediterranean region (EPPO website, accessed 20/05/05). The EPPO have produced a standard that describes in detail, diagnostic protocols for *P. cinnamomi* including examination of symptoms, isolation, identification of the pathogen through morphological characteristics, immunological and molecular methods, and reporting (OEPP/EPPO, 2004). While the EPPO document is a good model for the production of national standards, it is immediately apparent that a number of the recommendations would be unacceptable, or would at least provoke strong debate in Australia. For example, the EPPO Standards describe a single-baiting technique although a number of researchers in Australia advocate double-baiting to maximise recovery of *Phytophthora* species from soils and woody plant tissues (O'Gara, 1998; Huberli *et al.,* 2000; Drenth and Sendall, 2001; Davison and Tay, 2003). EPPO recommends the use of a single selective medium, although further debate and research is required on the wide range of media currently in use and their relative effectiveness.

In Australia, the vast majority of commercial detection and identification services use conventional morphological techniques for *Phytophthora* species. This is despite the availability of molecular methods that provide a faster result with a higher degree of resolution. There is simply not enough commercial demand for the improved technique, especially since it is likely to be more expensive than conventional methods. The actual and estimated costs of the molecular method are highly variable from $119 to >$300 per sample (Agtrans Research, 2004; I Smith and P O'Brien, *pers. comm.*). It is estimated that the cost will have to be no more than $30 per sample to be practicable (Agtrans Research, 2004). The cost of analysis by conventional means also varies widely according to the customer, the number of samples and the level of detail required, from $20 to $145 for a single sample.

Demand for *Phytophthora* diagnostic services is driven primarily by the needs of quarantine and primary industry, particularly the nursery industry since the recent inception of an accreditation scheme that calls for compulsory and regular testing (NIASA, 2003). The nursery industry rarely requires identification to a species level (Agtrans Research, 2004). Currently, throughput of samples is too low to make gains in the economies of scale that lead to lower prices, and laboratories will not be able to lower prices until there is increased throughput, technological efficiencies and probably both. Portable real-time PCR technology for the detection and identification of *Phytophthora* species in the field is currently under development, and would be a boon to the management of *P. cinnamomi* in natural ecosystems (Belbahri *et al*., 2005; USDA website, Vegetable and Forage Crops Research, accessed 20/05/05).

There are no national standards for reporting, recording or storing data relating to distribution of *P. cinnamomi* in the landscape. Within some States, isolation data is scattered between organisations, sample analysis laboratories and individual researchers. The Forest Management Branch of CALM in WA is the custodian of all data generated since the mid 1990s through the formalised departmental system of detection and diagnosis referred to as 'dieback interpretation' (McNamara, 2004).

3.5 Risk Assessment and Priority Setting

With many competing demands on the limited resources available to natural resource management in Australia, there is a great need to prioritise management and to target resources where benefits can be maximised. Risk assessment and priority setting processes have been developed only recently or are still under development in *P. cinnamomi* management.

Although the risk of *P. cinnamomi* can be assessed at different scales using a range of methods, a common goal of risk assessment is to identify where the impact of the pathogen is likely to be greatest. An essential first step in risk assessment is the mapping of areas of 'vulnerability' to disease. These have been identified in most States based on a variable range of factors including climate (particularly annual average rainfall), elevation, geology, soils and vegetation type. Some agencies have developed strategic or operational scale risk maps as a management tool using GIS technology.

In Tasmania, the presence of viable numbers of rare, susceptible, nationally and State listed plant species were criteria for the identification of 67 areas judged to be protectable in the long-term from *P. cinnamomi* (Schahinger *et al.,* 2003). One of the aims of the current project is to develop a risk assessment methodology, suitable for national adoption, also using threatened taxa as the basis for setting management priorities (Part 4 – Risk Assessment Models for Species, Ecological Communities and Areas). A regional scale risk assessment process is being developed in south-west of WA by the South Coast Regional Initiative and Planning Team NRM Group, which aims to identify disease-free areas having regional and community significance for protection from *P. cinnamomi*.

Current Practice in Risk Assessment and Priority Setting

Risk assessment is the process of analysing the risk using available information to determine the frequency and consequence of a specified event, and evaluating the risk to determine risk management priorities (AS/NZS ISO 14001:1996). One of the first steps in the analysis of the risk posed by *P. cinnamomi* is the identification of areas vulnerable to disease. It is generally accepted in Australia that *P. cinnamomi* does not cause severe damage in undisturbed vegetation at sites that receive mean annual rainfall less than 600 mm and are north of latitude 30º (Podger, 1999). However, further research on disease syndromes associated with *P. cinnamomi* such as that occurring in Northern Queensland may challenge this view. Most States in Australia have identified broad zones where biodiversity is vulnerable to the threat of *P. cinnamomi* due to the coincidence of susceptible vegetation and environmental conditions that are conducive to the establishment and persistence of the pathogen. The criteria used to identify zones of vulnerability vary from State to State (Appendix 1), reflecting different levels of knowledge and understanding of the disease with locality.

The NTAP states that the Australian Government will allocate funding for the management of *P. cinnamomi* in natural ecosystems based on:

- the degree of threat that infection by *P. cinnamomi* poses to the survival of a threatened species or ecological community
- the potential of that threatened species or ecological community to recover
- the number of threatened species likely to benefit from control in that locality
- the cost-efficiency and potential effectiveness of the control measures (Environment Australia, 2001).

One of the actions of the NTAP is the development of an agreed methodology for ranking areas for priority funding, on a nationally consistent basis. This would lead to the production of a national overview of priority regions and decision support systems to help land managers decide on locally appropriate methods of management (Environment Australia, 2001).

In accordance with the NTAP, the Australian Government DEH funded the development of a risk assessment method suitable for national adoption. The method was developed as another component of the current project to develop best practice benchmarks for management (Section 1 Introduction). A comprehensive review of risk assessment in natural resource management was undertaken (Part 3 - Risk Assessment for Threats to Ecosystems, Species and Communities: A Review) as a precursor to the development of the risk assessment models (Part 4 - Risk Assessment Models for Species, Ecological Communities and Areas).

The models were developed using a semi-quantitative scoring system which enabled a ranking of assets according to the risk posed by *P. cinnamomi* and the perceived ability to manage the risks. Models were developed for the following natural assets: i) flora, ii) fauna habitat, iii) vegetation communities, and iv) areas (Part 4 - Risk Assessment Models for Species, Ecological Communities and Areas).

The scores obtained for 'risk' and 'manageability' for each asset are designated a rating, and together with the conservation status, provide the basis for ranking. The ranked ratings, considered in conjunction with the conservation status, according to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), State listings, or The World Conservation Union (IUCN) criteria; provides the basis for decision making and priority setting in the management of natural assets under threat of *P. cinnamomi*. The models were tested Australia-wide by stakeholders directly involved in biodiversity conservation to make them nationally applicable generic models that can be readily adapted to local conditions (Part 4- Risk Assessment Models for Species, Ecological Communities and Areas).

Risk assessment can be defined as the processes of analysing and evaluating risks. A form of risk analysis that has been developed to a limited extent for *P. cinnamomi* management is risk mapping. In Victoria, a State risk map was developed for Parks Victoria showing the potential distribution and impact of *P. cinnamomi*. The risk map was constructed with a series of GIS overlays showing: i) areas in which topographic and climatic parameters are suitable for the pathogen, ii) the known distribution of the pathogen, iii) the distribution of susceptible species, and iv) the distribution and density of roads and tracks as a surrogate for the probability of pathogen transmission. Based on these parameters approximately 4,000km^2 of Park area in Victoria was determined to be conducive to the establishment and at high risk from *P. cinnamomi* (Gibson *et al.,* 2002). The risk classification system has been incorporated as an optional layer in the Parks Victoria electronic Environmental Information System (Parks Victoria, 2004).

The risk mapping process was greatly facilitated by the comprehensive Victorian floristic database (State Flora Information System) which comprises quadrat data for all vegetation work undertaken in Victoria and is based on five minute grid cells (Part 3 – Risk Assessment for Threats to Ecosystems, Species and Communities: A Review). The risk map has since been overlaid with maps of soils known to be conducive to the pathogen, based on published research and Department of Sustainability and Environment (DSE) experience over the last 30 years. Future mapping as part of the Victorian Strategic Plan (DSE, 2004) is intended to clarify the threat to various susceptible taxa and communities as a precursor to identifying areas for further on-ground evaluation of management requirements. From these on-ground appraisals DSE will be in a better position to weigh up the risks and management costs for consideration of the most effective use of resources (H Bramwells, *pers. comm*.).

A regional scale project, funded under the Australian Government Natural Heritage Trust–Regional Competitive Component (NHT-RCC) scheme, is currently being undertaken by the South Coast Regional Initiative and Planning Team (SCRIPT) Natural Resource Management Region in WA. Partnerships have been established with CALM and the WA DWG. The primary goal is to protect, in the long term and regardless of land tenure, the biodiversity of areas assessed as significant, valued by the community and at risk from dieback caused by *P. cinnamomi*.

As part of the project SCRIPT will:

- determine where there are still significant dieback free areas of native vegetation within the region
- apply a risk assessment methodology to determine areas at greatest risk and assess their manageability
- encourage community involvement through awareness education and seeking the nomination of areas for assessment and possible investments in management
- develop plans for the management of *P. cinnamomi* in specific areas identified as having regional and community significance.

Another proposal for funding has been submitted to the NHT-RCC investment scheme, to extend the knowledge and tools developed in the current SCRIPT project to other regions in the South-West of WA affected by *P. cinnamomi*. It is proposed that risk assessment maps at a strategic scale will be produced and 'dieback priority protection areas' identified. Management of the areas will be facilitated by operational scale risk assessment and the production of management maps. Training and extension activities will be undertaken to promote best practice management. At the time of writing, the outcome of the application was unknown.

The Mundaring Shire in WA carry out *P. cinnamomi* risk assessment of road reserves. Using digital aerial photography, a qualified ecologist categorises road reserve vegetation as being at 'High', 'Medium' or 'Low' risk based on the quality and structural integrity of the native vegetation. 'Medium' or 'High' risk vegetation is perceived to be in good to excellent condition and at the greatest risk of negative impacts associated with the pathogen. The vegetation categories, together with other relevant factors (such as slope, drainage and watercourses), are entered into the Shire's GIS as a specific 'dieback' layer. The risk rating system and database facilitates the development of operational plans with appropriate *P. cinnamomi* hygiene measures for activities carrying a high risk of introducing or spreading the pathogen such as road, drain and path construction and maintenance (McCarthy, 2005b).

A catchment scale model was developed using quantitative modelling techniques to predict the distribution and impact of *P. cinnamomi* in the eastern Otways of Victoria (Wilson *et al*., 2003). The following variables were recorded at 50 sites: aspect, slope, altitude, proximity to road, road characteristics, soil profile characteristics vegetation attributes and *P. cinnamomi* infestation status. A logistic regression model was spatially extrapolated over the study area and predicted that up to 74% (11,875ha) had a high probability of being affected by *P. cinnamomi*. As the area actually infested at the time of the study was small this study clearly presented an opportunity to explore appropriate management tactics to minimise the further spread of the pathogen (Part 3 - Risk Assessment for Threats to Ecosystems, Species and Communities: A Review).

State-wide mapping units (1:25,000) in the Tasmanian floristic database (TASVEG) have been categorised, on the basis of their perceived susceptibility to *P. cinnamomi*, as either; reliably highly susceptible, reliably not susceptible or having variable susceptibility. The three categories are intended to support management planning and assist districts to identify areas where *P. cinnamomi* requires management during operations. The susceptibility ratings should be used in conjunction with pathogen distribution maps available in State Government databases (Schahinger *et al*., 2003).

The identification of '*P. cinnamomi* Management Areas' in Tasmania recognises the need to set management priorities based on the level of risk to susceptible threatened species, and the manageability of those risks, to ensure the maximum benefit for conservation investment. The areas were identified based on the presence of viable numbers of rare and susceptible plant species and communities and the capacity to provide long-term protection against infection by *P. cinnamomi* (Barker *et al.,* 1996; Schahinger *et al*., 2003). Priorities for management included 12 species listed in the Australian Government's EPBC Act. However, also targeted were areas containing species listed under the Tasmanian *Threatened Species Protection Act 1995*, and plant communities perceived to be reliably highly susceptible according to TASVEG. Mechanisms for the implementation of management in the areas are set out in the Strategic Regional Plan for Tasmania (Schahinger *et al*., 2003).

Risk areas have been identified in South Australia based on the perceived capacity for *P. cinnamomi* to become established. 'High risk areas' are where *P. cinnamomi* is known to be present or is likely to become established, 'moderate' where *P. cinnamomi* is not known to occur but where there is potential for establishment, and 'low' where it is unlikely that the pathogen could become established. Within the risk areas, risk zones are identified based on confirmed or suspected presence of *P. cinnamomi*. The SA DEH uses the zoning system in Park management, and strategies deployed for *P. cinnamomi* management depends on the risk zone and the proposed activity. The cross-agency Phytophthora Technical Group has advocated the adoption of this system by other land managers (PTG, 2003).

A risk assessment process for specific areas in South Australia that are a high conservation priority is currently under development. The aim is to prioritise 20-25 listed plant species that may be threatened by *Phytophthora*, for research and management. The risk assessment method utilises a scoring system in which scores are assigned for the following parameters:

- the conservation status of the threatened species (S)
- the proximity of the threatened species to a *Phytophthora* infestation and the risk zone or area rating of the infestation (P).

A total score is calculated by (S) × (P) enabling scores to be ranked. Threatened species with a higher score have a higher research and management priority and vice versa (Velzeboer *et al.,* 2005).

In 1999, CALM adopted a protocol to progressively identify 'protectable areas' for priority management of *P. cinnamomi*. For the purposes of the protocol, 'protectable' is defined:

- within the vulnerable zone of WA
- deemed, by a qualified 'dieback interpreter', to be uninfested
- deemed by, a qualified 'dieback interpreter', to be not at risk of complete invasion by the spread of the pathogen within a timeframe of 2-3 decades.

Management priorities are set for protectable areas. Highest priority is afforded to areas with very high conservation values at risk e.g. declared rare flora, threatened ecological communities or habitat of threatened fauna. The protocol was developed in consultation with the WA cross-agency DCC, and is considered suitable for application on privately and publicly managed land (DCC, 2000). Management of protectable areas on CALM-managed lands focus on what is considered by the Department as the 'best available broadly applicable stratagem' of minimising human vectored spread of the pathogen by hygienic access (DCC, 2000).

As the need for treatment of vegetation in WA will always exceed resources available, CALM has developed detailed guidelines for setting phosphite treatment priorities. The following broad priorities apply:

PRIORITY A

- protect threatened and priority flora, fauna and ecological communities, (threatened flora and fauna are those declared under the WA Wildlife Conservation Act as likely to become extinct, are rare, or are otherwise in need of special protection)
- strategic applications to protect other conservation, landscape and heritage values
- local endemic representations of flora or fauna habitat.

PRIORITY B Rehabilitation projects and commercial values such as timber, recreation and/or wildflowers.

A scoring system has been developed to rank and further prioritise assets that meet the criteria of 'Priority A'. These assets may qualify for funding from CALM's Phosphite Operations Budget, which is part of a broader strategy to protect threatened assets. Projects that do not involve threatened or priority flora, fauna or communities, and operations to protect commercial values need to be funded under alternative budget allocations (CALM, 1999b).

Current Gaps in Risk Assessment and Priority Setting

Government land management agencies in temperate Australia commonly categorise areas based on the concentration of susceptible species, and manage those areas accordingly. However, there is little evidence that formal risk assessment processes are widely employed in setting priorities for biodiversity conservation. Some risk assessment methodologies, such as the identification in Tasmania of '*Phytophthora* management areas, have been developed relatively recently (Schahinger *et al.,* 2003), while others are still under development (Velzeboer *et al*., 2005; Part 4 - Risk Assessment Models for Species, Ecological Communities and Areas).

The language used in the section above, which reviews current practice in risk assessment and setting management priorities, gives an insight into the knowledge gaps that hamper risk assessment. There is a recurrence of terms such as 'perceived susceptibility', 'perceived capacity', 'anecdotal evidence', 'semi-quantitative' and 'surrogate for the probability', which indicates a lack of empirical evidence and data necessary for risk assessments.

Many States have undertaken extensive floristic surveys and have excellent databases on the distribution of species and communities. However, empirical data is lacking on the current distribution and rate of spread of *P. cinnamomi*, its impact and extent of susceptibility in native vegetation. The issues surrounding the collection and management of data on the distribution and spread of *P. cinnamomi* in the landscape are discussed in detail in the previous section (Section 3.4 Detection, Diagnosis and Mapping).

The lack of hard data on the impact of *P. cinnamomi* on plant species and communities, are a distinct impediment to risk assessment and management of native vegetation Australia-wide. Insufficient research has been conducted in most States on the susceptibility of native plant species and communities generally, and specifically on the susceptibility of listed threatened species. Where data are lacking the criteria are by necessity arbitrary and qualitative and the resulting risk classes only have meaning relative to one another (Part 3 -Risk Assessment for Threats to Ecosystems, Species and Communities: A Review). Surrogates are often used in the absence of appropriate data, for example the use of road and track density as a measure of the potential for human vectoring in an area (Gibson *et al.,* 2002). The current distribution of *P. cinnamomi* in Australia is not well known and distribution maps are expensive to maintain. Many States/Territories have inadequate records on the level of susceptibility of native vegetation, particularly the susceptibility of listed threatened taxa and communities. There is little data available on the effectiveness of current management tactics, particularly hygiene measures, due to inadequate monitoring.

Data on the impacts of *P. cinnamomi* on native fauna is particularly sparse with authors highlighting the potential for detrimental effects on fauna by the degradation of habitat containing *P. cinnamomi* susceptible plant species (Wilson *et al.,* 1994; Christensen, 1997; Calver and Dell, 1998). For example, the distribution, density and reproduction of honey possums (*Tarsipes rostratus*) are governed by the availability of nectar and pollen, predominantly from proteaceous plants (Wooller *et al.,* 1999; Garavanta *et al.,* 2000; Wooller *et al.,* 2000). The known susceptibility of many of the plants species on which the possum depends (including *Banksia* species) puts this animal at great risk from *P. cinnamomi*. However, there is currently no empirical data to support these assertions.

Many of the current priority setting processes put a heavy weighting on threatened species that are listed in State and/or the Australian Government EPBC Act, in some cases because funding mechanisms favour them (DCC, 2000; Schahinger *et al*., 2003; Velzeboer *et al.,* 2005; Part 4 – Risk Assessment Models for Species, Ecological Communities and Areas). Some scientists feel that in focusing on listed species, there is a risk of failing to protect other valuable assets, such as large currently uninfested and otherwise ecologically healthy areas.

This brings us to another inconsistency in terminology. The Australian Government Department of the Environment and Heritage define areas of 'high conversation value' as those that are free of *P. cinnamomi* and contain threatened species or ecological communities or those species or ecological communities at imminent risk of becoming threatened, but have habitats that are environmentally suitable for the pathogen's establishment (Environment Australia, 2001). The definition varies with State. SA has adopted a broader definition of 'high conservation value' to include areas that:

- support a highly diverse range of species for the type of vegetation
- have significant remnant vegetation
- have a high number of endemic plant species
- have few pest plant species and are generally undisturbed (PTG, 2003).

As discussed in the previous section there are currently no standards for disease surveys, so that the data available varies in quality and format within and between States. There are also no standards for rating the susceptibility of species to *P. cinnamomi*. The list of *P. cinnamomi* hosts compiled by Dr Keith McDougall shows that the methods for determining species susceptibility and scales adopted for describing the level of susceptibility varied from researcher to researcher (Appendix 2). There is some debate amongst prominent *Phytophthora* researchers about the validity of assigning susceptibility ratings based on glasshouse or laboratory trials alone.

The definition of 'susceptible' in the glossary of this document is applicable only in the broadest sense; 'lacking the inherent ability to resist disease or attack by *P. cinnamomi*'.

Standard definitions are required for the range of responses that occur in the *P. cinnamomi*–host interaction.

Where data have been collected on *P. cinnamomi* and its impacts in Australia, the *ad hoc* nature of funding has resulted in incomplete datasets, or datasets have been obtained only from a concentration of research in particular areas (Schahinger *et al.,* 2003). All these factors affect the outcome of risk assessment in which the data are used.

Generally, the function of a risk assessment is to: firstly identify the risks, and secondly identify ways to reduce those risks. Where the cost of available risk reduction strategies is greater than the available resources, management priorities will need to be set. In general, the cost of managing risks needs to be commensurate with the benefits obtained (AS/NZS 4360:1999). A cost-benefit analysis can assist in setting priorities, and increasingly are necessary to justify funding amongst competing demands. However, in the case of *P. cinnamomi* management a full cost-benefit is not possible as there has been no long term monitoring to determine the efficiency and benefits of current practices.

The Centre for *Phytophthora* Science and Management at Murdoch University has commissioned a study to estimate the long-term economic consequences of failing or delaying substantial and sustained investment in research and management of *P. cinnamomi* in WA. Like the risk assessment processes discussed earlier, this cost-benefit analysis has been hampered by a lack of economic data on the impacts of *P. cinnamomi* in WA or elsewhere in Australia, and the lack of a method to put a price on the intrinsic value of biodiversity (Economic Research Associates, 2005). This inability was in the past, and will remain, a major impediment to gaining serious investment for biodiversity conservation in general and *P. cinnamomi* management in particular.

3.6 Standard Operating Procedures

Standard operating procedures, sometimes referred to as management guidelines or operations manuals, provide directions to ensure consistency in the operational activities of an organisation. Standard operating procedures reflect the policy of an agency and can form the basis for compliance auditing.

Many high quality standard operating procedures for management of *P. cinnamomi* have been produced in Australia. The Nursery and Garden Industry Accreditation Scheme has produced national guidelines (NIASA, 2003) for best management practice in production nurseries and growing media suppliers, with a strong emphasis on control of *Phytophthora* species. However, as there are no powers to enforce accreditation the uptake has been slow and the availability of planting material produced by best practice still limited.

A number of State land management agencies have developed standard operating procedures to provide direction to staff and contractors. Documents developed in WA by the CALM and the WA DWG have provided benchmarks for a number of standard operating procedures produced elsewhere in Australia. The WA Dieback Working Group has developed detailed guidelines for Local Government (DWG, 2000), bushland restoration (Dunne, 2005) and to support a Code of Practice for the extractive industries (DWG, 2004a). CALM and the SA Phytophthora Technical Group have produced *P. cinnamomi* management guidelines for use across tenure in those States (PTG, 2003; CALM, 2004c). The current document brings together relevant procedures in each State to produce the first national best practice guidelines.

Currently standard operating procedures for *P. cinnamomi* management in Australia are largely 'stand alone' documents and integration of *P. cinnamomi* with general environmental management issues is poor.

Current Practice in Standard Operating Procedures

The Nursery and Garden Industry Accreditation Scheme, Australia (NIASA) has developed national Best Management Practice Guidelines for production nurseries and growing media suppliers (NIASA, 2003). The Guidelines have been designed to provide direction for the professional and standardised operation of nursery and media production businesses, but also as a mechanism for assessment to gain and maintain voluntary accreditation under NIASA (NIASA, 2003). The Guidelines document technical and management requirements in each of the following areas: crop hygiene, crop management and general site management (NIASA, 2003). The appendices provide detail on specific elements of *Phytophthora* spp. control with accreditation requirements for the frequency of sampling, and recommendations for sample testing either at a commercial laboratory or self-testing through baiting of soil, media or water samples (NIASA, 2003).

In most States affected by *P. cinnamomi* some procedural guidelines have been developed for on-ground management of the pathogen in natural ecosystems. Those produced in Queensland (Worboys and Gadek, 2004) and NSW (SHDWG, 2003) are area or task specific and were developed with heavy reliance on management experience in WA, particularly that of the WA DWG. There are excellent examples of standard operating procedures and management guidelines developed in WA, SA, Tasmania and Victoria and they are briefly described below.

The two major agencies in WA providing advice and assistance for the on-ground management of *P. cinnamomi* are the CALM and the WA DWG. CALM has produced a three-volume set of guidelines, which provides detail on management of *P. cinnamomi* at all levels within the Department, from legislation and policy to on-ground management:

- Volume 1: Management Guidelines (CALM, 2003)
- Volume 2: Interpreter's Guidelines for Detection, Diagnosis and Mapping (CALM, 2001)
- Volume 3: Phosphite Operations Guidelines (CALM, 1999a).

The CALM manuals are regularly updated by the *Phytophthora* Management Coordinator, and are posted on the Departmental website to ensure that staff always has access to the most recent version. CALM recently produced Best Practice Guidelines for use by staff, contractors and volunteers on conservation estate lands managed by CALM (CALM, 2004c). Public consultation on the Guidelines was sought in 2004 but the results of that process are not yet available (CALM website – Dieback Response Framework, accessed 19/01/05).

Three key publications of the WA DWG are: i) Local Government Guidelines (DWG, 2000), ii) the guide for Managing Phytophthora Dieback in Bushland (Dunne, 2005), and iii) Best Practice Guidelines for the management of *Phytophthora* in the extractive industries (DWG, 2004a). As well as providing operational prescriptions for specific activities, the Local Government Guidelines also provides guidance on the development of goals, objectives and policy on *P. cinnamomi* management within Local Government (DWG, 2000). The WA DWG Local Government Guidelines are available on the CALM website. The appointment of a full-time WA DWG Project Officer, to liaise with Local Governments and the community to raise awareness of the pathogen and its impacts, has been crucial to uptake the Guidelines to date (Lewis *et al.,* 2000).

The Tasmanian DPIWE has produced interim guidelines for the management of *P. cinnamomi* in Tasmania containing information about the pathogen, the legal requirements for management, a process to define areas for management and determine management objectives, and recommended prescriptions (Rudman, 2004). The guidelines are designed to provide a standard approach to management of *P. cinnamomi* across 'the different sectors of the community and tenures', for planners, land managers and contractors (Rudman, 2004). Another excellent and complementary resource is the Tasmanian Washdown Guidelines, which provides standards and procedures for the cleaning of large and small vehicles and equipment to prevent the spread of plant diseases and weeds (Rudman *et al.,* 2004).

Parks Victoria commissioned best practice guidelines for the management of *P. cinnamomi* in Victorian parks and reserves (Cahill *et al.,* 2002). The guidelines have become an important internal reference and will be referred to in the revised Parks Victoria policy on *Phytophthora* management (D Peters, *pers. comm*.). The best practice management prescriptions have been adapted from the recommendations in the original Parks Victoria policy on *P. cinnamomi* (NPS, 1994), the comprehensive *P. cinnamomi* management manual written specifically for Brisbane Ranges National Park and Steiglitz Historic Park (Peters, 1995), and the guidelines produced in WA by the WA DWG and CALM.

The SA DEH have developed comprehensive Standard Operating Procedures "to protect the integrity of natural areas by minimising the risk of *Phytophthora* infestation and spread" on reserve lands (SA DEH, 2002a). A number of key organisations in SA have adapted Transport SA (Transport SA, 2000) and SA DEH guidelines for their own use including: local government (AHC, 2003), the Electricity Trust of SA (ETSA, 2002), community conservation groups (Reynolds, 2001), SA Water Corporation and the *Phytophthora* Technical Group (R Velzeboer, *pers. comm.*).

The *Phytophthora* Technical Group was formed with the aim of coordinating a whole-of-community approach to the management of *P. cinnamomi* in SA. Membership includes SA DEH, South Australian Research and Development Institute (SARDI), Forestry SA, Transport SA, the horticultural industry and local government. The management guidelines developed by the *Phytophthora* Technical Group by adapting the SA DEH and Transport SA Standard Operating Procedures, were designed to provide a framework for all organisations to use as a basis for their own management plans and operational procedures (PTG, 2003).

Alcoa's WA operation has developed *P. cinnamomi* management procedures for each stage of the bauxite mining process, which are fully integrated into the environmental management systems. The procedures documents are reviewed regularly and revised to include up-to-date information from research, refinement of management techniques and changes to mining methods (Colquhoun and Hardy, 2000; I Colquhoun, *pers. comm.*).

Current Gaps in Standard Operating Procedures

Although thousands of copies have been sold since the NIASA management guidelines were first developed (NIASA, 2003), there has been poor uptake of voluntary accreditation in the nursery and garden industry throughout Australia. Two hundred production nurseries and growing media suppliers were accredited under NIASA in 2003 (NIASA, 2003), and 107 retail nurseries are accredited under the Australian Garden Centre Accreditation Scheme (NGIA website – Accredited Garden Centres, accessed 16/02/05). In response to recent criticism that not enough is being done to control *P. cinnamomi* in the nursery industry (The West Australian, 2005a and 2005b), the Nursery and Garden Industry Australia (NGIA) responded that they have no powers to enforce accreditation, as the government has stipulated that the industry be self-regulating (The West Australian, 2005b). Projects that involve revegetation, and are funded by government, should stipulate the use of plant material from accredited sources (S Worboys, *pers. comm.*).

The risks of not controlling, or ineffective control of, *Phytophthora* species in nurseries and associated industries goes beyond the dispersal of species that are known to already occur in Australia. The Sudden Oak Death epidemic caused by *P. ramorum* in the United States and Europe has been attributed to the introduction of this species from its centre of origin via the booming international trade in nursery stock (Pain, 2004; USDA Forest Service, 2004). Additionally, the hybridisation of two exotic species of *Phytophthora* has led to the emergence of a new and aggressive pathogen of alder trees in Europe (Pain, 2004).

The experiences in the US and Europe, have serious implications for Australia's biosecurity and for the nursery and associated industries, but are beyond the scope of this document to address adequately. Suffice to say that the issue of movement of plant material into Australia and between States needs urgent attention from governments and relevant industries in the interest of the country's primary industry and the future of its biodiversity.

A recent assessment of *P. cinnamomi* management has identified the need for a single and agreed Code of Practice and standards that can be made available to land managers outside the conservation estate in WA (WWF and DCC, 2004). The current project, and in particular this document, will provide the basis for such a Code of Practice as there will be nation-wide consultation on the best practice approaches and new benchmarks set.

As described above many excellent standard operating procedures for *P. cinnamomi* management have been produced in Australia. However, many remain stand-alone documents and the extent to which the procedures are integrated into compatible systems such as fire and/or weed management is highly variable throughout the country. The poor integration of *P. cinnamomi* issues and considerations at all stages of management has been identified as a key gap and impediment to effective management of the threat it poses.

Despite a range of *P. cinnamomi* management guidelines produced by CALM and the WA DWG, the development of generic best practice guidelines has been identified as a priority issue for WA (WWF and DCC, 2004). An agreed and standardised approach for lands of all land tenure is seen as necessary to address the currently inconsistent and ineffective approaches to management of the threat across the South-West of Australia (WWF and DCC, 2004). The WA DCC intends to develop cross-tenure guidelines when the process of public consultation on CALM's guidelines for best practice management of *P. cinnamomi* is complete (CALM website, Dieback Consultative Council, accessed 19/01/05).

3.7 On-Ground Management

Current levels of knowledge about *P. cinnamomi* in natural ecosystems preclude its eradication from infested sites. Consequently the objectives of on-ground management are to: i) limit the spread of *P. cinnamomi* and, ii) to mitigate the impact of disease where the pathogen occurs.

On-ground management methods focus on reducing human vectoring to limit the pathogens spread of *P. cinnamomi* in the landscape. Containment methods include restricting human access to uninfested areas, and where access is permitted, the use of strict hygiene protocols to reduce the chance of infested soil, plant material and water being transferred from infested to uninfested sites. In SA, access may also be restricted to infested areas to reduce further spread of the pathogen. The effectiveness of containment methods, particularly of hygiene measures, is largely unknown due to a lack of monitoring.

The use of *P. cinnamomi*-free material is fundamental to preventing introduction of the pathogen to uninfested areas. However, 'clean' basic raw materials for road building and maintenance are difficult to obtain in Australia, and there are no standards for determining and certifying the disease status of the materials. The introduction of planting material to uninfested areas is also considered a high risk due to the unregulated production of plants for revegetation by some conservation groups, and poor uptake of NIASA accreditation by the wholesale and retail plant nurseries.

Impact mitigation methods for infested sites are currently extremely limited. Phosphite is used to protect endangered susceptible plant species or communities *in situ*, and to retard the spread of the pathogen at infestation boundaries in areas of high conservation value. Although research has also shown phosphite to be effective in Victoria, its use in management is largely limited to WA. Phosphite testing in other States is extremely limited. Even in WA, knowledge of the target and non-target effects is incomplete, and no alternative chemical treatments are known. Phosphite is currently not registered for use in native vegetation and consequently off-label permits are required for its use.

In Western Australia, plant species at extreme risk of extinction and/or critically endangered by *P. cinnamomi* are conserved *ex-situ*. The germplasm is conserved as seed and the program is part of the Millennium Seedbank Project. The seed is used in species recovery programs, and in research on the range and extent of susceptibility to *P. cinnamomi* in threatened taxa.

Disease mitigation includes restoration of sites affected by *P. cinnamomi*. However, programs to restore biodiversity values have been sporadic, largely confine to WA and mostly ineffective. Urgent work is needed in this area.

Current Practice in On-Ground Management

Limiting the spread of the pathogen in the landscape is central to *P. cinnamomi* on-ground management (Cahill *et al.,* 2002). There are currently no proven methods to prevent the autonomous spread of *P. cinnamomi*, and spread by animals is usually very difficult and prohibitively expensive to control. However, as human vectoring spreads *P. cinnamomi* more widely and more rapidly than any other method of transmission, on-ground tactics focus on the modification of human activities and behaviours to reduce the risks of pathogen transmission.

Methods for minimising the likelihood of human-vectored spread of *P. cinnamomi* range from the complete prohibition of human access, which is enforceable by law, to discouraging access through the use of information and signage. The management of access is sometimes referred to as 'quarantine', because the purpose is to isolate either uninfested areas from disease, or isolate infested areas so that the pathogen cannot be dispersed more widely in the landscape.

Legislation such as the WA *Conservation and Land Management Act 1984*, the South Australian *National Parks and Wildlife Act 1972*, and the Tasmanian *Plant Quarantine Act 1997* empowers land managers in those States to restrict human access to areas threatened by *P. cinnamomi.* 'Discouraging entry' or legally restricting access most suits remote populations of threatened species, such as the highly susceptible, endemic, small populations *Epacris limbata* occurring in Douglas Aspley National Park in Tasmania (DPIWE, 2000).

Approximately 36% of State Forest in WA has been proclaimed 'Disease Risk Area' under the *Conservation and Land Management Act 1984*. Fines are imposed for unauthorised entry to gazetted areas in WA and SA (CALM, 2003; R Velzeboer, *pers. comm*.). The Forest Management Regulations 1993 in WA state that in a Disease Risk Area 'it is an offence if a person does not cleanse or disinfect as directed by an authorised person' (CALM, 2003).

Statutory restrictions are most commonly evoked to protect areas that contain susceptible assets of high conservation or socio-economic values, or uninfested areas from *P. cinnamomi* (CALM, 2003; SA DEH, 2002a; Rudman, 2004). However, non-statutory restrictions can be imposed at the discretion of the land manager to achieve similar management objectives. In SA, human access to infested areas may also be restricted to minimise the likelihood of the pathogen being spread further into the landscape (SA DEH, 2002a). Access may be permanently restricted to areas that contain high conservation values, or temporarily restricted on a seasonal basis when environmental conditions are conducive to pathogen proliferation and dissemination. Land managers may chose to restrict all access (Figure 3.7.1) or just vehicular traffic while still permitting activities such as bushwalking, cycling and horse riding, which are perceived in some States to pose a low risk of introduction.

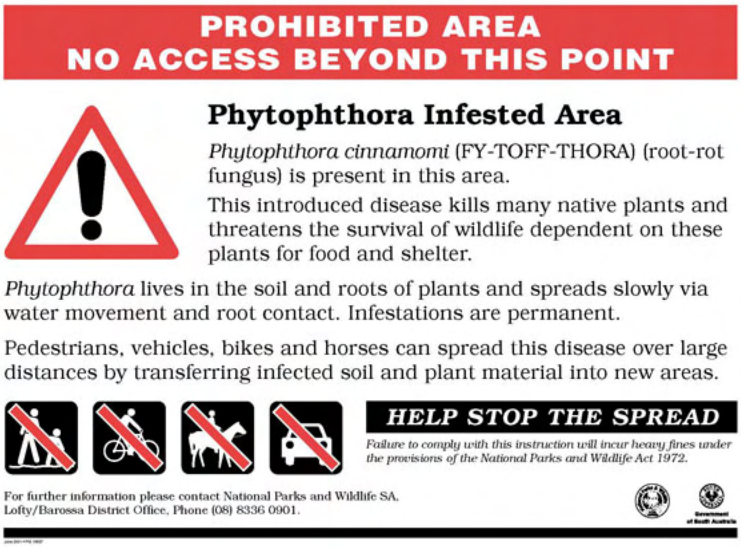

Figure 3.7.1 A sign used by the Department for Environment and Heritage in South Australia to inform that all access is restricted to a *Phytophthora* infested area, with the aim of minimising pathogen spread, and that non-compliance is an offence that can attract a fine (Image courtesy of R Velzeboer, Department for Environment & Heritage in South Australia).

When access to an area is to be permanently prohibited, the methods of road closure must ensure that unauthorised use cannot continue. The methods and standards of permanently closing and rehabilitating roads recommended by CALM include, mechanical ripping of a portion of the road/track surface and/or the use of logs (>400mm diameter) and other debris to block the entrance (Figure 3.7.2) (CALM, 2003). Other structural barriers such as gates and fencing are used to restrict pedestrian and vehicle access. Non-structural barriers such as signs, bunting and flagging tape, paint 'blazes' on trees, pegs and cones (Alcoa Procedural Control Documents; CALM, 2001) are used during mining and forestry operations in WA to demarcate disease boundaries, and to trigger access and hygiene procedures by staff and contractors.

The location of roads and trails will also influence the spread of *P. cinnamomi* in the landscape and should be carefully planned. For example, roads and walking tracks should not traverse wet areas unless they are bridged, and should be located downslope of threatened species and communities.

A crucial component of access restriction is the use of signage to communicate to all land users the aims, conditions and period of the restrictions. CALM in WA have opted for a graphically simple style, with a short and clear message, but without mention of penalties for unauthorised access to gazetted areas (CALM, 2003). In contrast, signage in SA for gazetted sites contains information about the pathogen and a warning that the restriction on access is legally enforceable (SA DEH, 2002a).

The combination of access control and hygiene is currently considered the best practice in containing the spread of *P. cinnamomi* in the landscape. Restricting human access to an area can be considered a form of 'hygiene'. However, hygiene also refers to specific procedures designed to prevent the dissemination of *P. cinnamomi* by ensuring that infested soil, water and/or plant material are removed from machinery, vehicles, equipment and footwear before they enter uninfested areas.

Figure 3.7.2 Permanent closure of a track in Waychinicup National Park in the south-west of Western Australia, by mechanical ripping of a portion of the track, and blocking of the entrance with a log and debris (Photo: E O'Gara).

Hygiene procedures are recommended for anything that can harbour potentially infested soil or plant material which ranges from large industrial machinery to light vehicles, bicycles, tools, footwear, tent pegs, horses hooves, construction materials, road building materials, composts, plants and water. The first principle of managing human access to uninfested areas is to be 'clean on entry'. Some organisations have produced detailed instructions on how 'clean' is attained (DWG, 2000; SA DEH, 2003; Rudman *et al.,* 2004).

Alcoa developed a 'green' strategy in which all haul roads were built of uninfested material under strict hygiene procedures and all vehicles cleaned as they entered the mine from public roads or forest tracks. This 'green' haul road system was instigated because cleaning vehicles as they moved from infested haul roads into the disease-free forest was expensive (loss of production time) and the effectiveness of cleaning a large muddy vehicle on a wet day is low (Colquhoun and Hardy, 2000).

All vehicles entering the Alcoa Huntly Bauxite Mine in WA, which is situated in an area of jarrah forest that is largely uninfested, must go through an automated wash-down facility (Figure 3.7.3), after which the operator must perform a visual inspection of the vehicle to ensure wash-down was effective, before proceeding onto the site (Alcoa Procedural Control Documents). Hygiene is also a key management strategy for the control of weeds in Australia and procedures are well developed and supported by government and primary industry. Permanent wash-down facilities for trucks and light vehicles, often free of charge, are available in many rural towns. In a campaign called 'Kill the Weeds…Stop the Seeds', the Queensland Department of Natural Resources and Mines have published a map and listing of wash-down facilities locations in the State (Natural Resources and Mines website – Weeds Washdown Facilities, accessed 02/09/05).

Due to the mosaic distribution of *P. cinnamomi* in the landscape, there are many instances where permanent or semi-permanent wash-down infrastructure is not available when and where it is needed. Portable wash-down systems enable machinery and vehicles to be cleaned at the point of risk and are used for disease and/or weed control during field operations (Colquhoun and Hardy, 2000; SA DEH, 2003a; DPI, 2004; Rudman, 2004). They may be large commercial units or small self-assembled systems (Rudman, 2004). High pressure hot water systems are recommended for cleaning earth moving equipment in Victoria, as the hot water assists in killing rather than simply removing *P. cinnamomi* (Smith, 2002). The hygiene prescriptions developed for fire response on Kangaroo Island in SA, provide step-by-step instructions for obtaining, assembling and deploying portable wash-down units (Figure 3.7.4) (SA DEH, 2003a).

A group of stakeholders in Tasmania concerned about *Phytophthora* and weed control have developed recommendations to standardise hygiene procedures for a range of machinery, vehicles and small equipment (Rudman *et al.,* 2004). As mentioned above the use of hygiene procedures to control weeds in Australia is well supported by government and primary industry. The Queensland Department of Natural Resources and Mines have developed excellent resources in an attempt to standardise methods of hygiene for weed control including: hygiene guidelines, guidelines for the construction of wash-down facilities, hygiene inspection guidelines, and standardised hygiene inspection forms (Natural Resources and Mines website – Weeds Washdown Facilities, accessed 04/04/05).

Where wash-down facilities are not provided, 'clean on entry' requires a sense of responsibility, and good organisation by individuals. Many of the hygiene measures are based on the principle that 'it is easier to keep clean than to get clean', leading to three key recommendations: i) postpone activities during wet weather, ii) begin activities with clean vehicles/equipment, and iii) avoid wet or muddy areas during activities.

Figure 3.7.3 The automatic wash-down facility at the entrance to Alcoa's Huntly bauxite mine in the south-west of Western Australia, designed to remove soil from trucks and light vehicles entering the mine, thus minimising the probability of introducing *Phytophthora cinnamomi* to the predominantly disease-free site (Photo: E O'Gara).

Figure 3.7.4 A portable wash-down unit. This type of system is used widely in South Australia and Western Australia to wash vehicles and equipment during general field and fire-fighting operations (Photo courtesy of R Velzeboer, Department for Environment and Heritage in South Australia).

Hygiene measures commonly call for the minimisation of water during cleaning, as wash-down effluent also poses a risk of spreading the pathogen. To reduce the amount of water required for effective wash-down it is recommended that large clods of dirt are firstly removed with a hard brush or other tool (DWG, 2000; PTG, 2003; Worboys and Gadek, 2004). Dust and grime need not be removed (DWG, 2000; CALM, 2003; PTG, 2003).

A system for working hygienically across infestation boundaries had been developed in WA (CALM, 2003) and Tasmania (Rudman, 2004). CALM uses the 'barrier system' when forestry operations straddle an infestation boundary, to prevent contamination of the uninfested part of the site. Logs are used to mark the infestation boundary. The operation is split so that certain tasks are restricted to the uninfested part of the site with clean machinery, vehicles and equipment and other tasks to the infested area with separate machinery, vehicles and equipment that are not subject to hygiene (Figure 3.7.5). It is crucial that drainage across the boundary is also managed (Rudman, 2004).

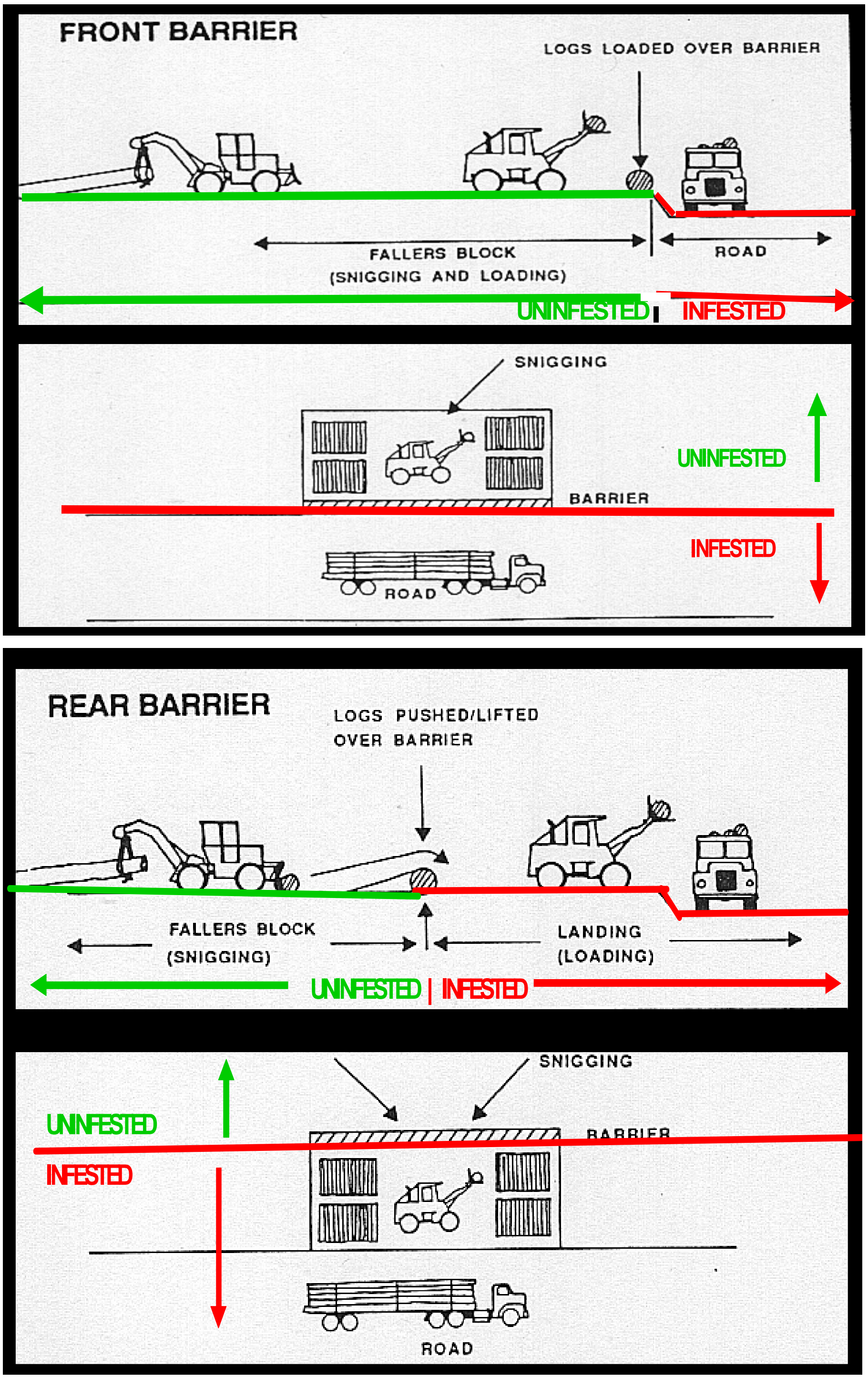

Figure 3.7.5 Diagrams of the two types of 'barrier system' employed by the Department of Conservation and Land Management in Western Australia to prevent the spread of *Phytophthora cinnamomi* to uninfested sites during operations that traverse infestation boundaries disease (Diagram courtesy of K Vear, Department of Conservation and Land Management, Western Australia).

Although activities involving the use of heavy machinery and vehicles present a significant risk of spreading *P. cinnamomi* infested soil, non-vehicular activities are not without risk. Where high conservation values are at stake, activities such as bushwalking, horse riding and cycling may pose an unacceptable risk of introduction. In recent years, SA DEH have been active in promoting hygiene to the general public, and have produced detailed guidelines for bushwalkers and horse riders giving details abut *Phytophthora*, responsible access and hygiene procedures (SA DEH, 2002a and 2003a). SA DEH developed the idea of a 'hygiene kit' for the cleaning of footwear and small equipment (Figure 3.7.6), which they encourage bushwalkers to assemble and carry (SA DEH, 2003a), and require all SA DEH vehicles to be equipped with (SA DEH, 2002a).

Figure 3.7.6 A 'hygiene kit' containing equipment and information to facilitate the cleaning and disinfection of footwear, small tools and equipment against *Phytophthora*. The Department for Environment and Heritage in South Australia actively and widely promote the assembly and use of such kits. (Photo courtesy of R Velzeboer, Department for Environment and Heritage in South Australia).

In situ apparatus for footwear hygiene ranges in sophistication from a simple tray and brush system (Figure 3.7.7) to a system developed by Parks Victoria nicknamed the 'Anakie Scrubber' (Figure 3.7.8). The footwear bath of the Anakie Scrubber, which contains disinfectant, is designed to minimise evaporation, prevent the entry of rainfall and animal access. This equipment will require less maintenance by Park staff (D Peters, *pers. comm.*).

Methods for mitigating the impact of *P. cinnamomi* at infested sites in Australia include the use of phosphite, *ex-situ* conservation of flora under threat of extinction, and restoration of infested sites. The application of phosphite, and *ex-situ* germplasm conservation, are relatively well developed tools, particularly in WA, compared to restoration of sites degraded by disease.

Figure 3.7.7 A boot cleaning station in Fitzgerald River National Park in the south-west of Western Australia, consisting of: a metal pan and lid into which soil is brushed from footwear with the brush provided, brief instructions (on the lid) and a plea to bushwalkers for cooperation (Photo: E O'Gara).

Figure 3.7.8 The 'Anakie Scrubber' footwear cleaning station consists of a metal ramp and disinfectant bath with an immersion plate for the cleaning of footwear prior entering uninfested areas to protect from the introduction *Phytophthora cinnamomi* (Photo courtesy of D Peters, Parks Victoria).

Since the early 1990s phosphite (also referred to as phosphonate), the anionic form of phosphonic acid (HPO_3^{2-}) has been successfully used in WA to reduce the impact of *P. cinnamomi* in natural ecosystems (Hardy *et al.,* 2001). The main focus of phosphite use by CALM is the protection of critically endangered flora species. Phosphite is currently being used in WA to maintain highly susceptible and critically endangered *Banksia brownii*, where the only remaining populations occur on sites already infested by the pathogen (Barrett *et al.,* 2003). It is also being used in an integrated management program to contain the spread of *P. cinnamomi* from a localised infestation in Fitzgerald River National Park, which is renowned for its rich biodiversity and high numbers of rare and endangered flora and fauna species.

The beneficial properties of phosphite include:

- the induction of resistance to *P. cinnamomi*, in otherwise susceptible plant species (Guest and Bompeix, 1990)
- its mobility in phloem and xylem (Ouimette and Coffey, 1990) enabling application by trunk injection to trees and large shrubs (Hardy *et al.,* 2001)
- the uptake of phosphite through foliage which enables it to be applied as a foliar spray, either manually or by broad scale aerial application (Barrett, 2003)
- it has a simple chemical structure and current data indicates that it has low mammalian toxicity and breaks down rapidly in the soil (Guest and Grant, 1991).

In the management of remnant bushland by community conservation groups, the WA DWG recommends the application of phosphite to susceptible vegetation in infested and partially infested sites, at sites where the disease status is unknown, and on uninfested sites if susceptible plants develop disease symptoms (Kilgour, 2000a). Phosphite is readily available in rural supply stores and the cost of materials for the trunk injection of a medium sized jarrah tree is estimated to be less than $0.50 (Dunne, 2005). However, phosphite application can be time-consuming, with labour costs making it an expensive option. Community groups avoid these costs by using voluntary labour, their own and/or other voluntary labour forces, to undertake the treatment (C Dunne, *pers. comm*.).

Aerial application (Figure 3.7.9) is a rapid way to treat entire plant communities especially where rough terrain would make ground application prohibitively expensive (CALM website – Dieback Phosphite, accessed 11/04/05). Foliar application using backpack (Figure 3.7.10) or trailer-mounted sprayers is usually restricted to small areas such as small reserves, small areas of remnant bushland or spot infestations (Hardy *et al.,* 2001). Trunk injection of trees and large shrubs is used in strategic areas where their loss would have a high visible impact, and where foliar application is impractical (Hardy *et al.,* 2001).

Figure 3.7.9 Foliar application of phosphite by backpack mister (Photo courtesy of B Shearer, Department of Conservation and Land Management, Western Australia).

Figure 3.7.10 Aerial application of phosphite in Stirling Ranges National Park in the south-west of Western Australia (Photo courtesy of G Freebury, Department of Conservation and Land Management, Western Australia).

Conserving flora *in-situ* is one of the most important objectives of CALM in WA, however, with no definitive or quick solution to the threat of *P. cinnamomi*, *ex-situ* conservation may be the last hope in conserving some of the States susceptible flora (Cochrane, 2001). In WA, *ex-situ* conservation of germplasm in seed banks is a well established technique (Anon, 2004; Cochrane, 2001; Cochrane, 2004). Although flora can be conserved as pollen, tissue/cell culture, DNA or living plants, the conservation of seed has many benefits: as it only requires simple technology, costs and pace requirements are relatively low, most flowering plants produce seeds which can be stored for long periods with little loss of viability, the technique is applicable over a wide range of species, and there is wider genetic representation in seed than in vegetative material (Cochrane, 2004).

Initially, a major focus of the seed conservation program in Western Australia was on species at risk from *P. cinnamomi*, and currently half the species stored are threatened by the pathogen (Anon, 2004; Shearer *et al.,* 2004). The WA seedbank program has expanded in recent years to include species threatened by habitat fragmentation, changes in hydrology and naturally rare species (Shearer *et al.,* 2004; S Barrett, *pers. comm*.). In partnership with the Botanic Gardens and Parks Authority of WA in the Millennium Seed Bank Project, seed collections made in WA are duplicated for the Millennium Seed Bank. The seeds are stored in facilities in the UK and maintained by The Royal Botanic Gardens Kew (Cochrane, 2001). The conserved seed facilitates the implementation of species recovery plans in WA by providing the basis for the translocation of rare and threatened flora (Cochrane, 2004; Royal Botanic Gardens Kew - Millennium Seedbank Project website, accessed 18/04/05). An additional benefit of the WA seed bank has been the provision of material to the Senior *Phytophthora* Research Scientist in CALM for trials to extend knowledge on the range of WA plant species that are susceptible to *P. cinnamomi* (Cochrane, 2004; Shearer *et al.,* 2004).

Translocation is being used increasingly in WA to mitigate the impact of *P. cinnamomi*. Translocation as defined by the Australian Network for Plant Conservation is the 'deliberate transfer of plants or regenerative plant material from one place to another' (Australian Network for Plant Conservation website, accessed 18/04/05). Translocation includes the following techniques:

- re-stocking - increasing the size of the existing population
- re-introduction – establish a population where it formerly occurred
- introduction – establish a population where it is not known to have occurred, within the known range and habitat
- conservation introduction – establish a population in an area that is outside the known range, which has appropriate habitat.

An initial program to undertake experimental translocation of 10 species in WA was funded in 1998 by the Natural Heritage Trust, and the method is now used in conjunction with a range of other recovery actions to conserve State-listed critically endangered species (L Monks, *pers. comm*.). Translocation, usually by 'introduction' and 'conservation introduction', is one of the management measures applied as part of recovery plans for critically endangered plant species for which *P. cinnamomi* is a threat.

Tables of on-ground management options for the management of *P. cinnamomi* in natural ecosystems have been compiled in Section 5 On-Ground Management Options, from the current best practice in Australia. A flowchart preceding the tables provides guidance on the appropriate use of tactics according to climatic conditions (primarily rainfall distribution), presence of susceptible plant species and disease status of the site. On-ground management tactics are presented for a range of activities that vary in the risk of introducing *P. cinnamomi* to uninfested sites, or spreading *P. cinnamomi* from infested sites.

Gaps in On-Ground Management

The most significant gap in on-ground management is a lack of acceptable methods to eradicate *P. cinnamomi* from an infested site. As discussed in Section 3.2 Research, there are renewed calls for urgent research in this area, which should not discount radical methods, so that options are available to deal definitively and swiftly with localised infestations in areas of high conservation value.

One of the major objectives of the NTAP for *P. cinnamomi* is to 'improve effectiveness and efficiency of management' through an evaluation and refinement of current management methods and hygiene procedures (Environment Australia, 2001). However, there is still limited information on the effectiveness of various management options, particularly hygiene measures. The potential for *P. cinnamomi* spread is very high in the bauxite mining process. However, Alcoa claim that a series of monitoring projects have demonstrated that investment in management procedures (estimated in 2000 at US$1.5M per year), training and the employment of disciplinary measures or contract penalties for operators has been effective and has kept the spread of *P. cinnamomi* to a minimum during bauxite mining in the jarrah forest (Colquhoun and Hardy, 2000). Managers of conservation lands have limited resources and to achieve management objectives require the cooperation and commitment not only of staff and contractors, but also the general public. There is an urgent need for monitoring, to determine the effectiveness of containment and hygiene measures under a range of environmental and social conditions in Australia's conservation estate.

For some issues there are currently no recommendations, for example, the safe removal and disposal of soil or plant material from infested sites. For other issues, such as the use of disinfectant in water for wash-down and fire fighting, there is a lack of empirical data to support a single approach and recommendations differ around the country. South Australia, Tasmania and Victoria advocate the use of a disinfectant in wash-down of vehicles and machinery (Peters, 1995; Cahill *et al.,* 2002; SA DEH, 2002a; PTG, 2003) and/or in water for fire-fighting (Rudman *et al.,* 2004; I Smith, *pers. comm*.). In WA, the use of disinfectant in these applications is considered unnecessary in most cases.

Current recommendations for the management of drainage is to direct it away from uninfested areas to infested areas or to the lowest point in the landscape (Rudman, 2004; CALM, 2003; DWG, 2000). However, many questions remain regarding the long-term effects of mixing strains of the pathogen, increasing the concentration of inoculum low in the landscape, and potentially making infested sites wetter than normal or for longer periods.

On-ground management tactics currently vary between and within States which is partly due to a lack of information on the effectiveness of the methods. In Section 5 On-Ground Management Options, management tactics that are currently widely accepted around Australia have been complied for infested and uninfested sites and those of unknown disease status. However, further research on the various management methods will enable the tactics to be refined.

The use of phosphite is an effective and key management strategy in WA (Hardy *et al.,* 2001). Despite evidence of its effectiveness (Aberton *et al.,* 1999; Aberton *et al.,* 2001) its use in Victoria has been limited (Cahill *et al.,* 2002). In other States/Territories it has been inadequately trialled in natural ecosystems. Although phosphite and its applications have been extensively researched, knowledge of the target and non-target effects is incomplete, and phosphite still has a number of limitations as a management tool including:

- phosphite provides only temporary protection to susceptible plants and treatment needs to be repeated and ongoing
- phosphite enables an infected plant to mount a defence against infection, but at recommended rates *does not* kill *P. cinnamomi* (Pilbeam *et al.,* 2000; Wilkinson *et al.,* 2001). Consequently, treated plants can be infected but remain asymptomatic, and thus have the potential to spread the pathogen to uninfested sites. This has implications for the use of phosphite in the nursery industry
- different species and genera of plants have different tolerances to phosphite dosage and there is a fine balance between the rates of phosphite applied, the development of phytotoxicity symptoms, and the control of disease (Hardy *et al.,* 2001). Differential tolerance to phosphite has implications for the effective and safe broad scale treatment of whole communities
- to prevent phytotoxicity lower concentrations of phosphite are applied to foliage, compared to trunk injection. The result is that the protective benefits of foliar application are comparatively short-lived (Hardy *et al.,* 2001). Aerial application normally provides approximately two years protection, whereas trunk injection can provide up to five (CALM website – Dieback Phosphite, accessed 11/04/05)
- the effectiveness and persistence of phosphite has been tested on a relatively narrow range of susceptible species and communities in Australia
- recent research indicates that phosphite has the potential to reduce pollen fertility and affect seed germination (Fairbanks *et al.,* 2001; Fairbanks unpublished data)
- the effect of phosphite on fauna and other non-target organisms has been inadequately studied

- there is some evidence to suggest that where phosphite is used repeatedly there is a tendency toward phosphite-tolerant populations of *P. cinnamomi* (Dobrowolski *et al.,* 2003), this needs further and urgent research
- the Australian Pesticides and Veterinary Medicines Authority (APVMA) administers the National Registration Scheme for Agricultural and Veterinary Chemicals (NRS) in partnership with the States and Territories. Phosphite is currently not registered for use in native vegetation, and therefore an 'off-label permit' may be required from the APVMA before use. It is recommended that the APVMA or the relevant APVMA State/Territory Co-ordinator be contacted for advice on permit requirements before the experimental or operational use of phosphite on native vegetation.

The documented benefits of phosphite currently outweigh its limitations, and many of the limitations can be addressed through research and good management. Faced with the continued threat that *P. cinnamomi* poses to a significant proportion of our native vegetation, the most responsible recommendation is that phosphite be used judiciously as part of an integrated management program, while further research continues into its optimal applications and limitations.

The construction and maintenance of roads and tracks without hygiene measures, and with infested road building materials has been implicated around Australia in the current widespread distribution of the pathogen in the landscape (Marks and Smith, 1991; Stretch *et al.,* 1992; Worboys and Gadek, 2004). Under the Victorian *Flora and Fauna Guarantee Act 1988* the use of gravel infested with *P. cinnamomi* is listed as a key threatening process (DSE, 2004).

Current best practice recommends the use of pathogen-free road construction materials at sites that are uninfested or where the disease status is unknown. In the event that pathogen-free material is unavailable it is recommended that the introduction of road-building material is avoided. There will be many instances in which neither of these recommendations will be practical. An inability to secure *P. cinnamomi*-free road construction materials, particularly gravel, is the most significant factor preventing full implementation of disease management procedures by Local Governments in WA (Lewis, 2000).

CALM in WA have an 'in-house' process by which gravel pits on CALM land and for CALM use can be 'certified' *P. cinnamomi*-free by personnel accredited by the Department in the identification and diagnosis of the pathogen (CALM, 2003). There are informal systems in place in Tasmania and Victoria where *P. cinnamomi* experts assess the disease status of quarries through surveys of disease symptoms of vegetation in the pits and drainage lines into and out of the pits, and/or sampling and analysis for the presence of the pathogen (T Rudman and I Smith, *pers. comm*.). As there is no current standard protocol for the method and frequency of sampling required (Section 3.4 Detection, Diagnosis and Mapping), assessments on disease status of pits subjected to *ad hoc* sampling are likely to be unreliable.

The Tasmanian Quarry Code of Practice provides principles, acceptable standards and suggested measures on all aspects of the extractive process to improve environmental outcomes, including the management of *P. cinnamomi* (DPIWE & DIER, 1999). A Code of Practice was developed in WA with the extractive industry, specifically for management of *P. cinnamomi* (DWG, 2004b) and includes best practice guidelines (DWG, 2004a). Both Codes were developed through a consultative process with the industry and between agencies with expertise in *P. cinnamomi* management and the industry (DPIWE, 1999; DWG, 2004b). Although the best practice guidelines are being followed by a number of larger operators, reliable sources of pathogen-free basic raw material continues to be a problem (C Dunne, *pers. comm.*).

Similar dilemmas occur with the introduction of planting material to uninfested sites or sites of unknown disease status. Current best practice is avoiding the introduction of planting material, but if introduction is necessary then plants should be obtained from NIASA accredited suppliers. However, the number of accredited suppliers is low as uptake of the scheme has been poor, and the peak body, the NGIA, have no powers to enforce standards (The West Australian, 2005b).

Additionally, there are concerns among some *Phytophthora* scientists in Australia that disease management measures in the NIASA Best Practice Guidelines are not adequate to control the pathogen. In nurseries, the use of chemicals (such as phosphite) that suppress disease, pose a risk that plants sold are infected although asymptomatic. The emergence of a new species of *Phytophthora* in Europe, which is an aggressive pathogen of alder trees, has been attributed to conditions in nurseries being favourable for hybridisation between species of *Phytophthora* (Brasier, 2003). The rapid spread of the alder pathogen through Europe, and the current epidemic of disease in native forests of the U.S., caused by *P. ramorum*, have been attributed to the movement of infested material as part of the international nursery trade (Brasier *et al*., 1999; Brasier, 2003; Hansen, 2003). The potential ramifications for Australia of the introduction of a new species, or hybridisation of existing species, of *Phytophthora* are much wider than just threats to biodiversity and include threats to the nation's primary industries. Cooperation between the industry, policy makers, land managers and scientists must continue and be expanded to address these problems.

Another concern is the well-intentioned but dangerous practice of community groups producing their own planting material for revegetation. As there are currently no controls on the conditions under which the material is produced, and much will be produced in the absence of appropriate hygiene measures, it poses a very high risk of harbouring *P. cinnamomi* and other plant pathogens.

Disease mitigation includes the rehabilitation of sites affected by *P. cinnamomi*, but this approach has only been applied to a limited extent in Western Australia and Victoria (Cahill *et al.,* 2002). Early rehabilitation efforts in Victoria focused on restoring the productive values of degraded forests, appear to be successful (I Smith, *pers. comm.*). However, there has been little effort and less success in restoring natural values to sites where *P. cinnamomi* has had a significant impact.

Under agreements between Alcoa and CALM, Alcoa has a program to restore *P. cinnamomi* affected jarrah forest that occurs within the mining lease, but is not suitable for mining (Anon, 1996). Alcoa invests approximately $300,000 per annum in the program in which 50-100ha of disease affected jarrah forest are restored with a focus on biodiversity values (I Colquhoun, *pers. comm.*).

3.8 Monitoring, Audit and Review

Monitoring, audit and review refers to the processes necessary to close the loop of continuous improvement in *P. cinnamomi* management. Monitoring provides information necessary for evaluating the risk *P. cinnamomi* poses to biodiversity and the effectiveness and efficiency of risk mitigation measures.

Monitoring to evaluate the spread and impact of *P. cinnamomi* is undertaken to some degree in all States, but has been insufficient to determine the direct and indirect long-term impacts of *P. cinnamomi* on biodiversity. Knowledge of the impacts of *P. cinnamomi* on native fauna is particularly poor. Monitoring of spread and impact is currently carried out under a range of programs, with varying objectives and methods, and often through the endeavour of dedicated individuals with no security of continuance. Monitoring for new incursions even where high conservation values have been identified has been inadequate to protect biodiversity in Australia.

Other than an evaluation in a bauxite mining operation in the jarrah forest by Alcoa in WA, monitoring of the effectiveness and efficiency of *P. cinnamomi* management procedures has been extremely limited in Australia. Consequently, the effectiveness and cost-efficiency of measures, such as hygiene, is unknown. Although the effectiveness of phosphite in reducing the spread and impact of *P. cinnamomi* is being monitored, largely in WA, the target and non-target effects are still largely unknown.

An evaluation of the effectiveness and review of management requires knowledge of the level of compliance to standard operating procedures. Alcoa in WA has adopted an accredited Environmental Management System (EMS) through which independent auditing of *P. cinnamomi* management procedures is undertaken every 4 years. Alcoa also undertake annual internal audits of operational performance and procedural compliance in relation to *P. cinnamomi* management.

Current Practice in Monitoring, Audit and Review

It is a legislative requirement that NTAPs are evaluated and reviewed by an independent expert every five years. The NTAP for *P. cinnamomi* (Environment Australia, 2001) will be reviewed by June 2006. Part of the strategic plan for the management of *P. cinnamomi* in Victoria is the establishment of a steering committee and the development of a 'monitoring and evaluation plan' to ensure that each phase of the plan is being implemented according to the original objectives (DSE, 2004). Like the NTAP, the Victorian Strategic Plan will be reviewed by an independent expert before the end of its three-year term to appraise the success or otherwise of its implementation and impact (DSE, 2004).

The West Australian Conservation Commission has statutory responsibilities under the *Department of Conservation and Land Management Act 1984* for monitoring and auditing the performance of CALM and the Forest Products Commission in carrying out and complying with approved management plans (WA Conservation Commission website – Audit Functions, accessed 17/06/05). The Forest Management Plan 2004-2013 considers *P. cinnamomi* the most significant threat to the health and vitality of many ecosystems and a high priority is given to minimising new infestations in areas that are uninfested (Dell *et al.,* 2005).

The WA Conservation Commission also has a role in auditing the implementation of the recently initiated State Government Dieback Response Framework for *P. cinnamomi* management, to ensure that on-ground action occurs in areas of highest conservation priority. Additionally, a pilot system is in place in WA in which the community play a role in auditing the implementation of the policy (CALM website - Media Statement, accessed 06/03/04).

Primarily, monitoring is undertaken in Australia by land management agencies, research institutions and industry. The purpose of monitoring ranges from: determining long-term patterns of pathogen spread and disease impact, determining the effectiveness of management measures, and/or surveillance of pathogen movement where high conservation values are under imminent threat.

CALM have a range of monitoring projects in WA. Sites for monitoring the spread and impact of *P. cinnamomi* in the south coast region were established in 1991-95, 1996 and 1997, with many additional sites established since 1999 at which monitoring of phosphite treatments is also being undertaken (S Barrett and M Grant, *pers. comm.*). Long term research plots totalling approximately 20ha, have been established in Banksia woodland between Mandurah and Augusta on the south-west coast. A 16-year monitoring program is showing an annual disease extension rate of approx 1m in the free-draining sands (C Crane, *pers. comm.*). Studies indicate that *P. cinnamomi* spreads at 0.7 - 2.3m per annum depending on the slope of the site, the nature of the subsurface soils and whether there is any additional subsurface runoff. At an average spread rate of 1.5m, 1.5ha of native vegetation in the south coast region is infested and modified for every 10km of *P. cinnamomi* disease front each year (Grant and Barrett, 2003).

In the jarrah forest of Western Australia, sites monitored by Dr Frank Podger in the 1960s (around the time the link was made between the disease syndrome and *P. cinnamomi*) were remeasured in the mid 1990s by CALM (K McDougall, *pers. comm.*). Dr Keith McDougall established long term monitoring sites in 1994/1995 from which floristic data from 100 or so quadrats is still being collected (K McDougall, *pers. comm.*).

The rate of *P. cinnamomi* disease extension was studied in the Jarrah Forest Bioregion, by the Forest Management Branch of CALM, by re-interpretation of 55 sites initially surveyed between 1986 and 1998. Like all the studies reported above, the measurements in this study were based on visible symptoms rather than direct measurement of mycelial growth. Not surprisingly, the rate of extension was greatest in incised water courses or gullies. The upslope spread on the Darling Plateau (East) was 0.37m/year, compared to 2.15m/year for the Blackwood Sedimentary Plateau where a perched water table provides long periods of favourable conditions conducive to proliferation of the pathogen (Strelein *et al.*, 2005).

In Tasmania, monitoring of heathland at Rock Cape and buttongrass moorland at Melaleuca was established in the late 1970s by Dr Frank Podger and continues today. Additionally, long term monitoring of *P. cinnamomi* impact on buttongrass moorland at Red Knoll and Bathhurst Harbour were established in 1998 (T Rudman, *pers. comm.*).

In Victoria, long-term studies have been undertaken in the Brisbane Ranges, Wilson's Promontory National Park, Grampians National Park (Weste *et al.,* 2002) and Anglesea (Wilson *et al.,* 1997). Longer term studies in the Brisbane Ranges and the Grampians have shown chronosequential changes in the floristic composition (Weste and Ashton, 1994; Weste *et al.,* 2002). Species present in post-diseased areas are likely to be either resistant to *P. cinnamomi*, exhibiting little or no disease symptoms, tolerant/fluctuating species that exhibit some disease symptoms as well as showing regrowth and recovery at times. Susceptible species (e.g. *Xanthorrhoea australis*) have regenerated from seed in the Brisbane Ranges (Weste and Ashton, 1994) and the Grampians (Weste *et al.,* 2002). A decrease in inoculum, due to the absence of a suitable host, would allow re-establishment of *X. australis* from the soil seedbank. However, it is not clear whether the regeneration is stable or whether successive cycles of disease and recovery will occur (Weste, 2003). Apart from *X. australis*, no other susceptible species were observed to regenerate in post-disease areas in this study. In the Grampians, Weste *et al*. (2002) recorded the return of 30 species in previously infested sites, however, two species failed to survive and six species failed to regenerate.

In New South Wales, permanently marked floristic quadrats were established in 2001-2002 in infested and healthy areas at Mt Imlay and Mt Sugarloaf in South East Forests National Park (K McDougall, *pers. comm.*). In SA, there is a yearly sampling program, if funding is available and weather conditions are favourable (SA DEH, 2002b; R Velzeboer, *pers. comm.*).

Research conducted by Alcoa in Western Australia since 1978 has contributed significantly to the understanding of the vectored spread of *P. cinnamomi*, and has led to many of the on-ground management tactics recommended in Section 5 On-Ground Management Options. Monitoring and sampling for *P. cinnamomi* from haul roads, mine pit floors and road-side sumps has provided evidence of the source of new infestations and has led to modifications to mining operations (Colquhoun and Hardy, 2000). Intensive monitoring of rehabilitated sites has led to significant changes in rehabilitation procedures improving outcomes. Each year, species richness is monitored in 15-month old rehabilitation, at a number of sites at each mine, and it has been found that the disease status of the soil does not affect species richness in early rehabilitation. A monitoring program is carried out annually when vegetation is one year old to identify opportunities to improve procedures (Colquhoun and Hardy, 2000).

The Sydney Harbour Federation Trust in NSW monitors sites before, during and after high risk operations to ensure management tactics are effective in minimising the spread of *P. cinnamomi* (G Bagwell, *pers. comm.*).

Although phosphite is currently a key management tool in WA, it is also an experimental treatment due to questions regarding non-target effects and the full range of target effects. CALM is monitoring areas in the Stirling Ranges and Fitzgerald River National Park where aerial application of phosphite was carried out to: protect critically endangered flora from disease and, to control the spread of *P. cinnamomi* in the landscape (Barrett, 2003). A localised infestation called the Bell Track infestation, in the otherwise disease-free Fitzgerald River National Park, has being closely monitored by CALM since the early 1990's. The reason for concern is that the disease front has reached the boundary of a poorly defined micro-catchment, and if it spreads to the two adjoining drainage lines a rapid and unchecked spread is predicted with catastrophic consequences for highly diverse, highly endemic flora and the habitat of a number of endangered and critically endangered fauna (M Grant, *pers. comm.*). Monitoring has shown that phosphite application to the Bell Track infestation reduced the spread of *P. cinnamomi* by at least 50%, but that phosphite needs to be applied at a minimum of 2-yearly intervals for maximum efficacy (M Grant, *pers. comm.*).

The WA DWG also conducts monitoring of reserves where phosphite was applied, to evaluate effectiveness of the treatment in reducing the spread and impact of the disease. The conclusion of monitoring nine reserves was that dry conditions in the period since their strategic treatment with phosphite led to reduced impact from disease (Glevan Dieback Consultancy Services, 2002). Refinement of the monitoring is planned with photo points, site surveys and the inclusion of untreated controls (C Dunne, *pers. comm*.).

Some land management agencies in Australia have adopted or are in the process of adopting EMS, which directly addresses policy and procedure in the management of *P. cinnamomi*. Some agencies have been compelled to adopt EMS under Regional Forest Agreements, e.g. National Parks and Wildlife Service and State Forests in NSW (AFFA website – Future Forest Management, accessed 23/06/05).

A number of EMS models have been developed throughout the world but they all embody similar principles. The Australia/New Zealand and International Standard EMS (AS/NZS ISO 14001:1996) provides a systematic and methodical approach to planning, implementing and reviewing an organisation's response to identified environmental impacts. It does not establish absolute requirements for environmental performance beyond commitment, in policy, to compliance with applicable legislation and regulation to continual improvement (AS/NZS ISO 14001:1996).

Alcoa undertake annual internal audits for operational performance and procedural compliance in *P. cinnamomi* management. The accredited EMS (AS/NZS ISO 14001:1996) adopted by Alcoa is audited by an independent auditing contractor every 4 years, and in recent years has been extended to *P. cinnamomi* management procedures. Alcoa is in the process of integrating the audit of *P. cinnamomi* management procedures with the broader environmental audit which is more efficient, but also ensures that management of the pathogen is considered central to the Company's environmental policy rather than a 'side issue' (I Colquhoun, *pers. comm.*).

All operations associated with mining and rehabilitation are audited including: exploration and drilling, clearing vegetation prior to mining, landscaping, control of access to the mine, maintenance of roads and tracks, washdown procedures, demarcation of infested areas, drainage and soil movement records. Environmental Officers, Supervisors and on-ground workers are interviewed and the mine physically inspected. The auditors assign a rating to performance, make recommendations and list actions for improvement, each action is assigned to a responsible individual to complete, and a tracking system ensures that it is acted upon (I Colquhoun, *pers. comm.*).

Gaps in Monitoring, Audit and Review

Reference to the necessity for monitoring the spread and impact of *P. cinnamomi* in different landscapes and under different management regimes can be found in most policies, management manuals, standard operating procedures and the numerous reviews of the issue. Despite this recognition, monitoring is limited and has been insufficient to provide an understanding of long-term trends in the distribution and impact of *P. cinnamomi* in natural ecosystems. The lack of such data has been a considerable impediment in the current project to the development of a risk assessment process for *P. cinnamomi* (Part 4 -Risk Assessment Models for Species, Ecological Communities and Areas). Monitoring is also insufficient to detect incursions of *P. cinnamomi* before it establishes at new sites.

Key components of the NTAP include State and regional scale monitoring and review programs to: ensure early detection of *P. cinnamomi* in areas of high conservation value, determine the long-term impacts of *P. cinnamomi* and, determine the efficacy of current management measures (Environment Australia, 2001). However, programs have not yet been implemented.

At the State level processes and resources are either unavailable for long-term or routine monitoring or auditing, or as is the case in WA, monitoring is carried out under a range of research or management programs by individual agencies with varying objectives and methods and with very little coordination of effort. CALM has undertaken only limited monitoring and auditing of approved operations in the conservation estate (Dell *et al.,* 2005).

The current management program for *P. cinnamomi* in Tasmania focuses on threatened biological assets, which is a direct response to the failure of concentrating management on the pathogen (Schahinger *et al.*, 2003). A suite of strategic management areas will be established to provide representative long-term protection of the species and ecological communities that are most threatened by *P. cinnamomi*. Previous approaches applied a set of generic prescriptions to activities carrying a high risk of spreading *P. cinnamomi*. However, resources to monitor compliance with management regulations, and pathogen movement were inadequate. Additionally, *P. cinnamomi* management recommendations put into regional and local plans were often ignored due to the high costs of following them where management may not be warranted (Schahinger *et al.*, 2003).

Monitoring of the spread and impact of *P. cinnamomi* has been inadequate to protect biodiversity even in known priority areas. The process of developing a risk assessment methodology to facilitate management of threatened assets, which is another component of the current project (Part 4 - Risk Assessment Models for Species, Ecological Communities and Areas), has highlighted a number of gaps in empirical knowledge. It is clear that the epidemiology of *P. cinnamomi* in the range of environments in which it can establish and persist is still largely unknown. Consequently, the methodology developed has had to rely on subjective assessments for many of the risk factors included in the models (Part 4 - Risk Assessment Models for Species, Ecological Communities and Areas).

SCRIPT identified similar gaps regarding the extent to which vegetation on the south coast of WA was affected by *P. cinnamomi*. As a result they are currently undertaking a study to assess where *P. cinnamomi* is causing disease in the south coast region, and to identify significant *P. cinnamomi*-free areas of native vegetation within the region using a risk assessment methodology.

The effectiveness of the current management tactics, particularly hygiene measures, has been a central question in the compilation of the on-ground management recommendations in Section 5 On-Ground Management Options. Other than monitoring undertaken in bauxite mines in WA by Alcoa, there has been very little work done to determine the effectiveness of on-ground management of *P. cinnamomi*, compliance with processes or procedures, or even the effectiveness of extension and community education programs. While data are being gathered on the effectiveness of phosphite to mitigate the impact of *P. cinnamomi* in vulnerable vegetation communities, there have been no significant efforts to study the effects on fauna, water quality or other non-targets.

Monitoring soil moisture dynamics is important for understanding soil-vegetation interactions and can be utilised to understand spread of disease. Recent advances in remote sensing using microwave technology have shown that soil moisture can be measured quantitatively under a variety of topographic and vegetation cover conditions (Tansey, 2005). Routine measurements from a satellite system, such as ENVISAT - the European Environmental Satellite, can be done at night and in the presence of cloud cover (Racette and Le Vine, 2005). The moisture content of the upper 1-2m of soil can be accurately measured and scatterometry can detect underground river and stream channels (Vienna University of Technology, 2002). The highest resolution maps of soil moisture, taken at times conducive for pathogen dispersal, will enhance risk assessments of pathogen spread and can be added to GIS databases.

Other than the systematic internal and external auditing through an accredited EMS by Alcoa, auditing of *P. cinnamomi* management procedures in Australia is extremely limited. The adoption of an EMS does not automatically ensure that *P. cinnamomi* will be adequately addressed by an agency. Workable procedures for *P. cinnamomi* management must first be developed, and an EMS can then provide a systematic and methodical approach to planning, implementing, documenting, auditing and reviewing the management. While an accredited EMS is best practice, the cost of accreditation will restrict uptake.

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