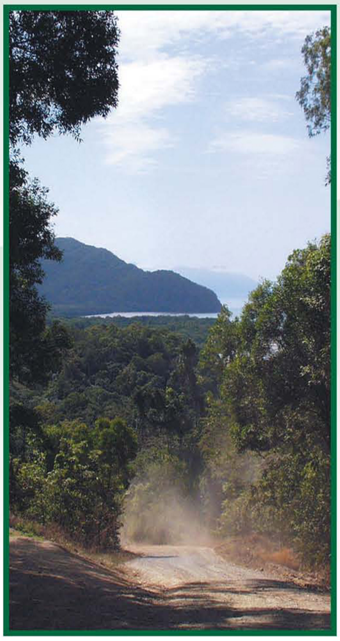
RESEARCH REPORT



# Rainforest Dieback: Risks Associated with Roads and Walking Tracks

Stuart Worboys and Paul Gadek

Rainforest CRC

Cooperative Research Centre for Tropical Rainforest Ecology and Management

# RAINFOREST DIEBACK: RISKS ASSOCIATED WITH ROADS AND WALKING TRACK ACCESS IN THE WET TROPICS WORLD HERITAGE AREA

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(*Top*) Rainforest CRC
(*Centre*) Steve Turton
(*Bottom*) Fiona Barron

April 2004

# TERMS OF REFERENCE

***Purpose of the Project***

The purpose of this project is to identify the risks posed by maintenance works and use of roads and walking tracks in identified dieback-affected rainforests, and to identify and recommend actions which could be implemented by management agencies to reduce the threat posed by *Phytophthora* species to native species and ecological communities.

The geographic foci of these recommendations are the Mt Lewis Road and the network of disused forestry tracks in the area proposed as part of a long-distance walking track in the Tully-Koombooloomba area and the tracks of the Kirrama area.

Key questions for which management advice is sought include:

- Are road or track surfaces, verges or their drainage structures infected by the *Phytophthora* fungus, and do they pose a dieback disease risk?
- If they do pose a risk, what is the level or extent of risk?
- Does the use or maintenance of these roads or tracks increase the risk of spread of dieback?
- Is the risk seasonal?
- What are the general and specific management measures which could be practically adopted to mitigate such threats?

***Constraints***

All persons employed on the contract will take every precaution to ensure that no damage to World Heritage values occurs either directly or indirectly as a result of their actions. All work must be undertaken in an environmentally sensitive manner and adequate hygiene measures must be employed to prevent the spread of the disease. Researchers will ensure that any permits, licences or other authorisations are obtained that are required by its employees or agents in undertaking this contract, including landholder approval for access and permits for investigating Aboriginal Cultural sites from the Department of Environment and Heritage.

***Objectives***

- To provide guidance on how to manage and minimise the risk of spreading or activating *Phytophthora cinnamomi* as a result of human access and associated activity;
- To increase knowledge of the effects of *P. cinnamomi* and the role of humans in spreading the pathogen; and
- To assess the level of risk of *P. cinnamomi* spreading to and infecting plant populations in two main focal areas.

***Tasks to be Performed***

- Identify and assess any correlation between known dieback outbreaks and the presence of roads and tracks in the Tully/Koombooloomba, Kirrama and Mt Lewis Road areas;
- Undertake an assessment of soil samples from road/track surfaces, road verges and associated drainage structures for the presence of *Phytophthora* infection; and

- Develop draft management guidelines and recommendations as applicable to soil-borne pathogen management within the World Heritage Area.

# CONTENTS

# ACKNOWLEDGEMENTS

Sandra Abell (School of Tropical Biology, James Cook University) provided data on distribution of *Phytophthora cinnamomi* from her Honours Research (Abell, 2002). Sandra also identified many isolates from outside her study areas.

Professor David Gillieson and Craig Harriss (School of Tropical Environmental Studies and Geography, James Cook University) provided advice and essential data for map preparation and data analysis.

Thanks to Ian Colquhoun for permission to adapt the West Australian Dieback Working Group's *Phytophthora* Management Guidelines for the Wet Tropics region. Any errors in adaptation of this useful document are ours alone.

The Wet Tropics Management Authority provided funding for this research.

WET TROPICS
MANAGEMENT AUTHORITY

# EXECUTIVE SUMMARY

***Research Objectives and Tasks***

The purpose of this project is to provide guidance on how to manage and minimise the risk of spreading or activating *Phytophthora cinnamomi* as a result of human access and associated activity in the Wet Tropics World Heritage Area. Specific focus was given to Mt Lewis Road, the area identified as part of the Misty Mountains long distance walking track in the Tully Falls-Koombooloomba area, and the disused logging tracks in the Cardwell Range, east of Kirrama.

This was undertaken by systematically collecting and analysing soil samples for the presence of *Phytophthora* infection; assessing any correlations between known dieback outbreaks and the presences of roads or tracks in these regions; and developing draft management guidelines and recommendations for soil-borne pathogen management within the World Heritage Area. A review of management literature was undertaken to identify management strategies applicable to, or that could be modified for, the tropical environment.

***Key Findings***

- The widespread occurrence of the known plant pathogen *Phytophthora cinnamomi*, reported for the Tully Falls region by Gadek *et. al.* (2001), was reconfirmed for this region and all other regions surveyed in this project.
- *Phytophthora cinnamomi* was detected at all sites where aggressive outbreaks – *patch death sites* – of this disease were evident. The trigger to aggressive behaviour of *P. cinnamomi* is at present unknown.
- Improved isolation and identification methodologies allowed the identification of several other species of *Phytophthora* in many of these regions.
- There was a significant correlation between roads, tracks and the distribution of *Phytophthora cinnamomi* in mapped dieback polygons in all regions surveyed except for the Lamb Range. The latter negative association is considered to be a function of the poor mapping of roads and forestry tracks in this region.
- A survey of the literature failed to identify any current guidelines for soil pathogen management in natural tropical ecosystems, although such documents have been developed for use in temperate zone situations.
- A list of tree species that persist on dieback sites in a healthy state is presented. These species may prove useful.
- A draft *Phytophthora* Dieback Management Strategy has been developed for use by the Wet Tropics Management Authority based on the National Threat Abatement Plan (2002). Procedures for on-ground implementation are provided.

***Further Research***

- Address the question of the status of *Phytophthora cinnamomi* in the Wet Tropics – is it an introduced species, or endemic?
- Monitor established sites and confirm findings for other areas of the World Heritage Area.
- Identify triggers to aggressive behaviour causing patch death sites, or ‘dieback outbreaks’.
- Investigate the role of other *Phytophthora* species in natural tropical ecosystems.

# 1. INTRODUCTION

*Phytophthora cinnamomi* is a fungus-like root-rotting pathogen with an extremely broad host range (Erwin and Ribeiro, 1996). It is soil-borne, and readily spread in soil or by surface or sub-surface water movement. It was first conclusively associated with dieback in jarrah in Western Australia in the mid 1960s (Podger, 1968), and since then its association with dieback has been widely reported in southern and eastern Australia (Weste, 1994).

The disease that *P. cinnamomi* causes in susceptible species can lead to the death of the plant. If many species in a community are susceptible, removal of entire suites of species can lead to fundamental changes in ecology, and threaten some with extinction (Weste, 1994). It therefore represents a significant threat to many native ecosystems across wetter parts of the continent. Its significance on a national scale has recently been recognised in its listing as a Key Threatening Process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and the development of a draft Threat Abatement Plan (Environment Australia, 2001).

*P. cinnamomi* was first found in upland tropical rainforests of north Queensland in 1975 (Brown, in Gadek, 1999). Soil isolations found it to be widespread, but not always in dieback-affected forests. In these initial surveys, an association between logged forest as well as the occurrence of feral pigs and higher percentages of *P. cinnamomi* isolations was also concluded (Brown, in Gadek, 1999). Brown’s field investigations ceased in 1981, but dieback-affected forests did not go away. In 1997, partly in response to concerns from the ecotourism industry, a preliminary report was commissioned by the Cooperative Research Centre for Tropical Rainforest Ecology and Management (Gadek, 1997), recommending a workshop of invited specialist researchers to provide expert guidance for further research. The workshop (Gadek, 1999) provided a foundation for the establishment of the current research program.

In 1999, whilst working on interpretation of aerial photographs for the Wet Tropics Management Authority (WTMA), David and Peter Stanton identified and mapped similar canopy dieback patches in upland rainforests in the Tully Falls/Koombooloomba, Lamb Range, Kirrama/Cardwell Range and Mt Lewis areas. Studies by (Pryce, 2000) of these mapped dieback polygons in the Tully Falls/Koombooloomba area found *P. cinnamomi* in soils in the area. Recent surveys by Abell (2002) found several species of *Phytophthora* in dieback-affected and unaffected forest areas, but *P. cinnamomi* was found to be significantly more abundant in dieback-affected areas.

In response to similar concerns for human-mediated spread of the pathogen in the Wet Tropics World Heritage Area (WTWHA), WTMA contracted James Cook University to:

- Identify and assess any correlation between known dieback outbreaks and the presence of roads and tracks in the Tully-Koombooloomba, Kirrama and Mt Lewis Road areas;
- Undertake an assessment of soil samples form road/track surfaces, road verges and associated drainage structures for the presence of *Phytophthora* infection; and
- Develop draft management guidelines and recommendations as applicable to soil-borne pathogen management within the World Heritage Area.

The report presents the outcomes of field-based and desktop research undertaken to address these tasks.

# 2. METHODS

## 2.1. DEFINITIONS

***dieback-affected***

Refers to an area of forest in which dead and/or dying canopy trees are clearly visible from the ground. Symptoms indicate the dieback is caused by an aggressive strain of *Phytophthora cinnamomi*, or that environmental conditions in the area are conducive to the occurrence of dieback.

***affected***

Refers to the presence of *P. cinnamomi* in soils in the area concerned. May or may not be associated with visible expression of symptoms.

***mapped dieback polygon***

Defined in Gadek (1999) and Pryce *et. al.* (2002) as *patch-death sites* – patches of apparent canopy death or thinning, identified from aerial photography, and transferred to a GIS layer. Size ranges from one to ten hectares. Mapped dieback polygons do not define areas of uniform impact or effect. Rather, these boundaries delineate locations where smaller patches of dead and dying canopies can be detected (D. Stanton *pers. comm.* in Gadek, 1999).

***study site***

Study sites were located within mapped dieback polygons, usually as close as practicable to a dieback-affected site. Unaffected study sites were located in nearby forest areas outside the mapped dieback polygon, with similar physical characteristics (Gadek, 1999).

***compass bearings and navigation***

In all field work, magnetic north was used as an approximation of grid north. Magnetic north lies approximately 7.0° east of grid north.

***datum***

All grid references are with respect to the Australian Geodetic Datum 1966.

## 2.2 FIELD WORK

### 2.2.1. Sampling Techniques

Study site selection for soil sampling was guided by the mapping of patch-death by Stanton and Stanton (Figure 1). Study sites were visited between October 2001 and September 2002. Areas of principal focus for this study were:

- Koombooloomba/Tully Falls;
- Mount Lewis;
- Lamb Range; and
- near Gunna Camp, in the Cardwell Range, southeast of Kirrama.

Study site positions were plotted on 1:50,000 army survey maps and, where possible, were confirmed in the field using a twelve channel Garmin GPS. All grid references presented are based on the 1966 Australian Geodetic Datum.

Pryce *et. al.* (2002) determined a minimum of three or four soil samples were necessary to reduce the chance of a false negative to less than five percent. Therefore, eight or sixteen samples were taken at each study site (1256 square metres), and the presence/absence of *P. cinnamomi* is reported on the basis of these multiple samples.

Soil samples, each with approximately 250 grams of soil were collected from each of the sites. Samples were stored in plastic clip-seal bags and returned to the laboratory for processing. Soil sampling equipment was surface sterilised with 70% ethanol after each sample was taken. Baiting of *Phytophthora* in creeks was carried out by semi-immersing whole, green Packham variety pears in the water, a few metres downstream from where the road crossed the creek. Pears were placed in wire mesh cages for protection from larger animals. The pears were left in the water for three to four days. Upon removal, they were wrapped in newspaper and returned to the laboratory for isolations. Areas of the fruit that appeared bruised or water soaked were surface-sterilised with 70% ethanol, and small sections of fruit at the edge of the discoloured area were removed and placed onto a selective medium. Culturing of any isolates proceeded as described in Section 2.1.2, following.

Opportunistic observations of dieback-affected forest were made along ridge-top tracks, and reports were received of dieback-like patch death in several upland localities of the WTWHA. It was not always possible to sample soil at these localities.

### 2.2.2. Lupin Baiting Technique

*Lupinus angustifolius* L., Fabaceae, (blue lupin) is a species of plant particularly susceptible to infection by *P. cinnamomi* (Chee and Newhook, 1965). A technique has been developed for baiting *P. cinnamomi* out of the soil using lupins (Pratt and Heather, 1972) and may also be useful for the baiting of some other *Phytophthora* species (Drenth and Sendall, 2001).

The roots of newly germinated lupins (seeds sourced from Mr Donald Spurs of Rockfield Pty Ltd, Latrobe, Tasmania) are placed in a 1:10 soil/water mix, which allows the zoospores to locate and infect the roots. After symptoms of infection were detected in lupin seedlings (i.e. lesions on the roots, wilting of the leaves), root sections were taken. The roots were removed from the water and surface sterilised by immersing for two minutes in 70% alcohol (Drenth and Sendall, 2001). They were then dried with sterilised paper towelling and cut up into sections of five millimetres in length. The root sections were placed onto an agar growth medium containing antibiotics, and designed to be selective for *Phytophthora*. This medium discourages growth of fungi and bacteria so that a pure culture of the target organism can be obtained. After two days the plated root sections were examined for growth of *Phytophthora*. If mycelium was detected, subcultures were taken and plated onto selective medium. After subculturing onto the third plate of selective media, hyphal tip subculturing was performed.

Since it is possible to have more than one individual or species growing within one root section culture (there may have been several infections of the same root), a hyphal tip subculturing technique was used to enable the detection of the presence of multiple individuals and species of *Phytophthora* in individual soil samples. The tip of an individual hyphal strand was located with the aid of a stereomicroscope, removed and placed onto a growth medium (10% Campbell’s V-8 Juice Agar).

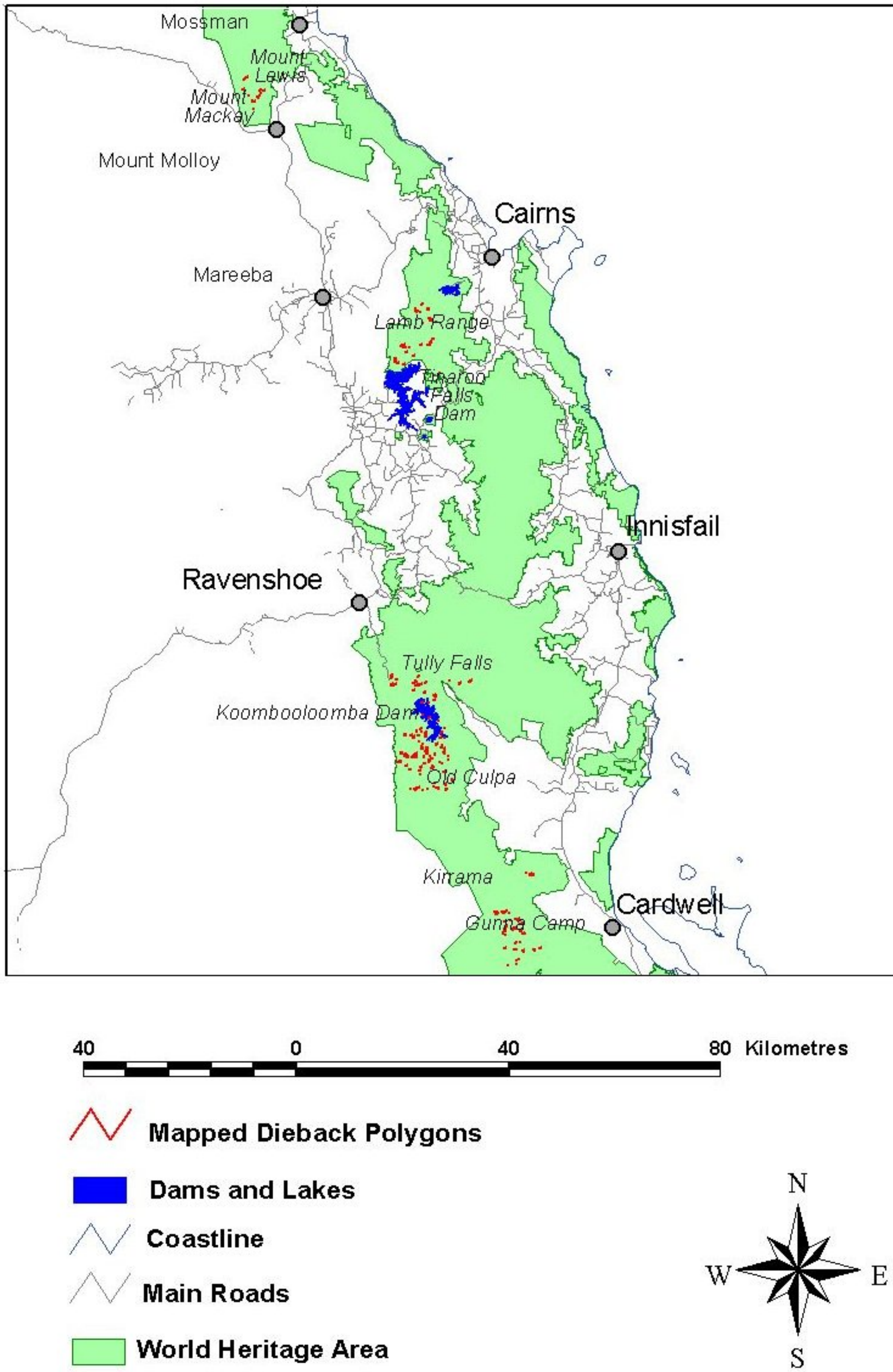


**Figure 1:** Mapped dieback polygons in the Wet Tropics World Heritage Area.

### 2.2.3. Morphological Identification

Prior to induction of sexual and asexual spores, the cultures were first examined for obvious morphological characteristics. Cultures were grouped using basic features and allocated to morphological groups (morpho-groups). This made it possible to deal with the large number of samples more effectively and to ensure that representatives of each group were later identified using molecular techniques.

Representatives of morpho-groups were induced to sporulate using a pond water wash (Drenth and Sendall, 2001). The reproductive characters were then used to attempt identification using the key of Waterhouse (1963) and the Revised Tabular Key (Stamps *et. al.* 1990).

### 2.2.4. Assessment of Mapped Dieback Polygon-Death Distribution

***Data Sources***

Regional GIS data were sourced from the GIS unit of WTMA. Coverages used in these analyses included:

- Webb and Tracey (1975) vegetation mapping;
- Geology based on 1:250,000 mapping by the Australian Geological Survey Organisation;
- Drainage digitised from 1:250,000 scale topographic mapping; and
- Roads digitised from various sources, including 1:50,000 topographic mapping.

These were supplemented by field observations. Mapping of dieback polygons is described in Gadek *et. al.* (2001), pages 3-4.

***Analysis***

Gadek *et. al.* (2001) found a significant negative relationship between mapped dieback polygon area, and the distance from mapped roads in the Tully Falls/Koombooloomba area. The method of Gadek *et. al.* (2001) was applied to data from the Kirrama, Lamb Range and Mt Lewis areas, to test if a similar relationship existed. The method of analysis was described as follows:

> *"The road vector dataset is based on 1:50,000 scale compilations and includes all formed roads from sealed surfaces to minor unsealed roads, e.g. snigging tracks to former log dumps. It would be difficult to accurately map minor tracks and walking tracks due to the high canopy coverage. Canopy death polygon areas (in hectares) were expressed as a fraction of each road buffer zone (100 metres wide). This is necessary to avoid bias due to the systematically reducing area of each buffer zone with distance away from the defined road."*

During fieldwork undertaken for this project, and during other field activities, the observation was made of dieback-affected forest along ridgelines, despite the findings of Gadek *et. al.* (2001), who found a consistent association of mapped dieback polygons with drainage lines. To investigate this observation further, the position in the landscape of the mapped dieback polygons was assessed.

The location of the mapped dieback polygon in the landscape was categorised as:

- **Ridge top** – located on a clearly delineated ridge separating two catchments;
- **Midslope** – the mapped dieback polygon is not located on a ridge or a creek; or

- **Creek** – the borders of the mapped dieback polygon include a creek, when mapped at a 1:50,000 scale.

## 2.3. LITERATURE REVIEW

To gain insight into the management of *P. cinnamomi*-related dieback in southern Australia, a review of existing research and management literature was undertaken. Little literature exists concerning the control of *P. cinnamomi* in tropical ecosystems. In developing management recommendations for minimisation of risk of *P. cinnamomi* spread, the following publications provided the framework:

Threat Abatement Plan for Dieback (Environment Australia, 2001)

Managing *Phytopthera* Dieback (Dieback Working Group, 2000)

Selection and Design of *Phytopthera* Management Areas for the Conservation of Threatened Flora in Tasmania (Baker *et. al.*, 1996)

Discussions and presentations at the *2nd International IUFRO Meeting on Phytophthora in Forests and Natural Ecosystems* were invaluable in focussing management directions. A draft set of recommendations was developed for activities in more sensitive environments of the WTWHA. These are structured around the goals of the Threat Abatement Plan.

# 3. RESULTS

## 3.1. FIELD ASSESSMENTS OF *PHYTOPHTHERA CINNAMOMI*

### 3.1.1. Dieback and Roads

The distribution of mapped dieback polygons with respect to roads has been assessed in some detail for the Tully Falls/Koombooloomba area (Gadek *et. al.* 2001). A significant correlation was found in this area, i.e. mapped dieback polygons were closer to roads than would be expected were they distributed at random. This was also found to be the case in the Kirrama/Cardwell Range area (Figure 2C), $r^2 = 0.1179$, $P < 0.05$, and in the Mt Lewis area (Figure 2B), $r^2 = 0.5089$, $P < 0.001$, but not in the Lamb Range area (Figure 2A), $r^2 = .01$, $P = 0.32$.

When compared with existing 1:50,000 mapping, and with the distribution of roads observed during field surveys of dieback, the GIS layer showing roads in the Lamb Range area is clearly incomplete. The lack of correlation between dieback-patch area and distance to nearest road may reflect the inadequacy of mapping data for this area.

A

B

C

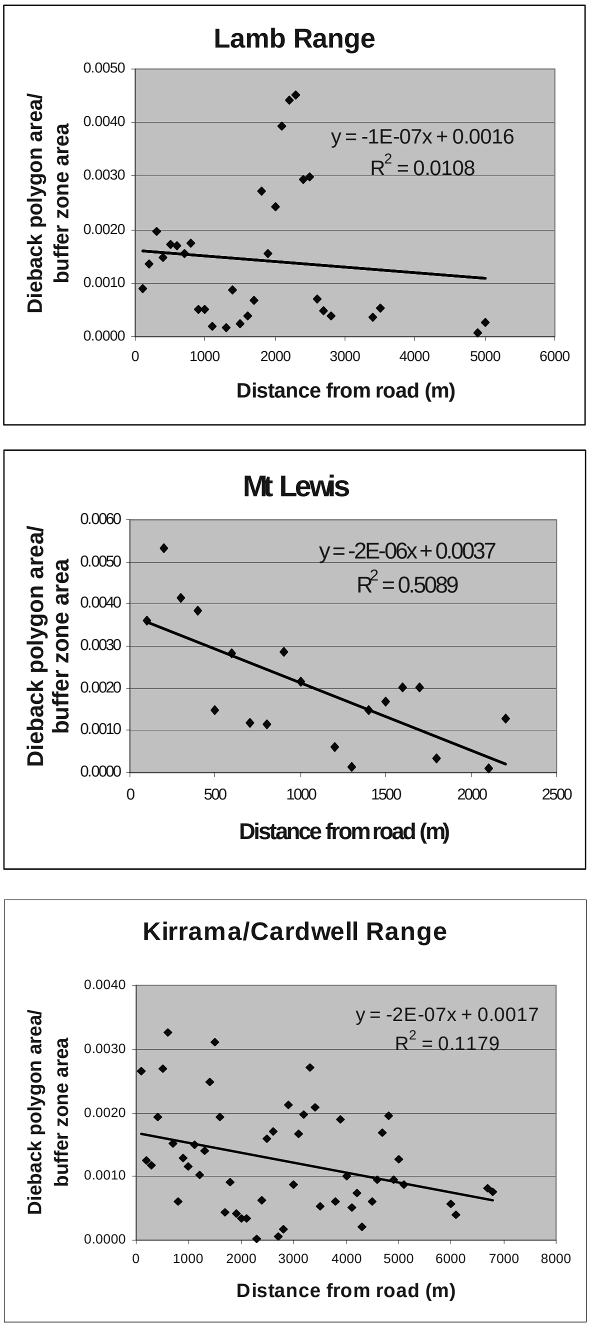


**Figure 2 A-C:** Proportional area of mapped dieback polygons within buffer zones around mapped roads in the (a) Lamb Range, (b) Mt Lewis and (c) Kirrama/Cardwell Range study areas.

### 3.1.2 Distribution of *Phytophthora cinnamomi* in the WTWHA

#### P. cinnamomi *isolations*

Positive isolations of *P. cinnamomi* from the current work, and from Brown (1975-1981) are reported in Figures 3, 4 and 5. Note that locality information on isolations by Brown was provided with an accuracy of ± 0.01° (= 1.1 km) (D. Gillieson *pers. comm.*), whereas localities plotted during the current study have an error of approximately 100 metres.

*P. cinnamomi* was isolated from study sites in all areas visited, but was not ubiquitous, reflecting the survey results of Brown. Isolations were generally in close proximity to roads, although isolations from an area of dieback-affected forest at Mt Mackay are an exception to this rule. Of twenty seven study sites, *P. cinnamomi* was isolated in twenty, although the species from two other sites have yet to be confirmed. Several other species of

*Phytophthora* were identified by Abell (2002), however their distribution and impacts will not be considered further in this report.

In addition to the mapped dieback polygons of Stanton and Stanton, reports have been made of dieback-like symptoms in several localities, mostly in upland areas of the Wet Tropics. Some of these have been visited, and are described briefly in Table 1.

**Table 1:** Other dieback sites visited, 2000-2001.

| Site Name | Grid Reference | Notes |
|---|---|---|
| Black Mountain (Harris Peak) | ~339500, 8158000 | Soils not sampled. Two small patches on ridge track at about 800-900 metres. |
| 'Devil's Thumb' access track, Karnak[1] | ~318000, 8186600 | Several small patches along ridge track at about 1000-1100 metres. Soils sampled. Isolates not yet identified. |
| Mt Mackay, southern Carbine Tableland | ~316083, 8160223 | Several large dieback areas, including one very large patch of very severe dieback (see frontispiece), of approx 0.5 hectares at 1165metres altitude. Isolates not yet identified. |
| Mt Spurgeon, northern Carbine Tableland | ~306750, 8182500 | Many dead or unhealthy *Eucalyptus grandis*. Forest in early stages of succession to rainforest. All understorey plants healthy. |

[1] Devil's Thumb is an unofficial name for a rocky pinnacle on the Main Range, west of Karnak. The official Devil's Thumb is located approximately seven kilometres south of the grid reference listed here.

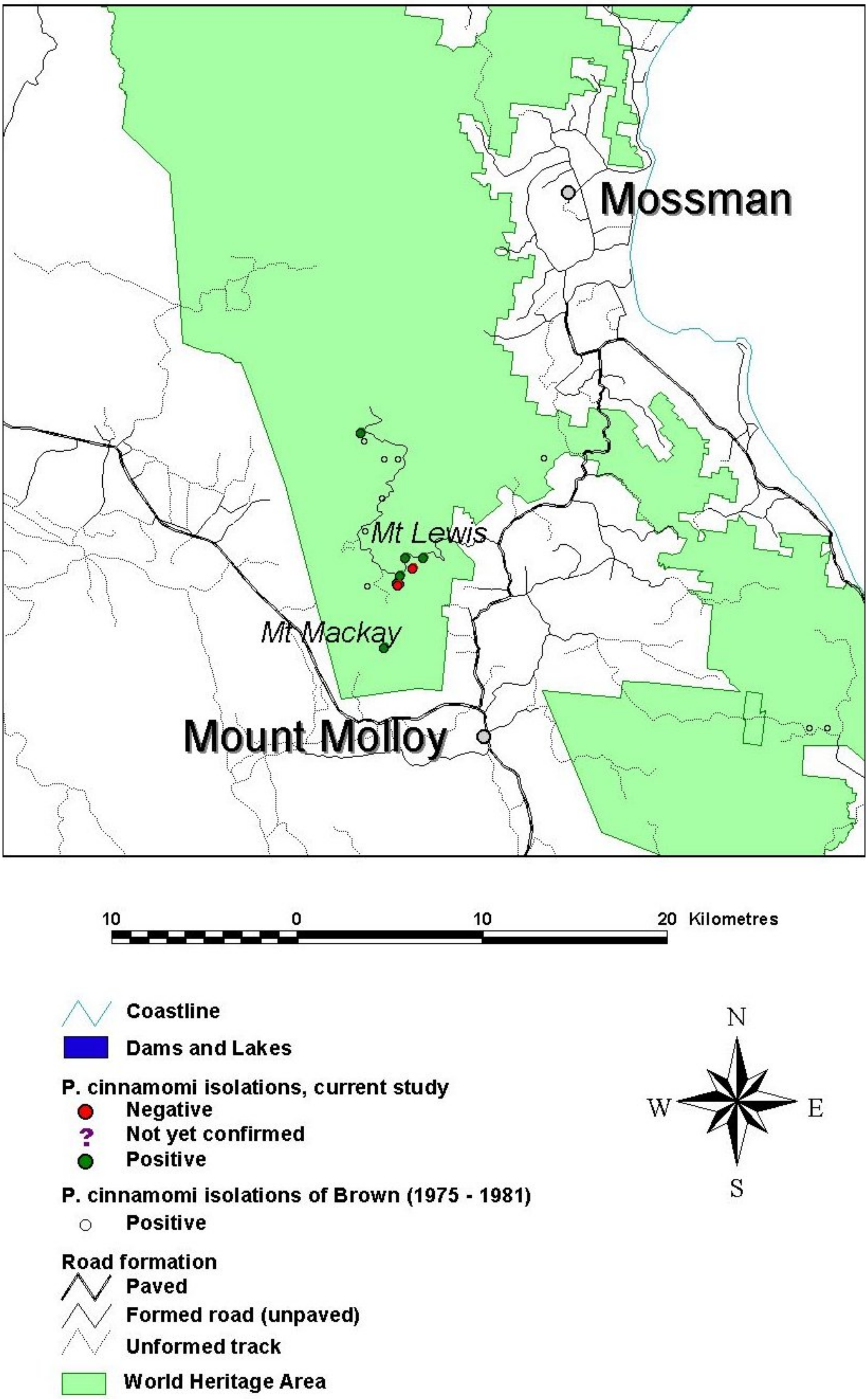


**Figure 3:** *Phytophthora cinnamomi* distribution (Mt Lewis study sites).

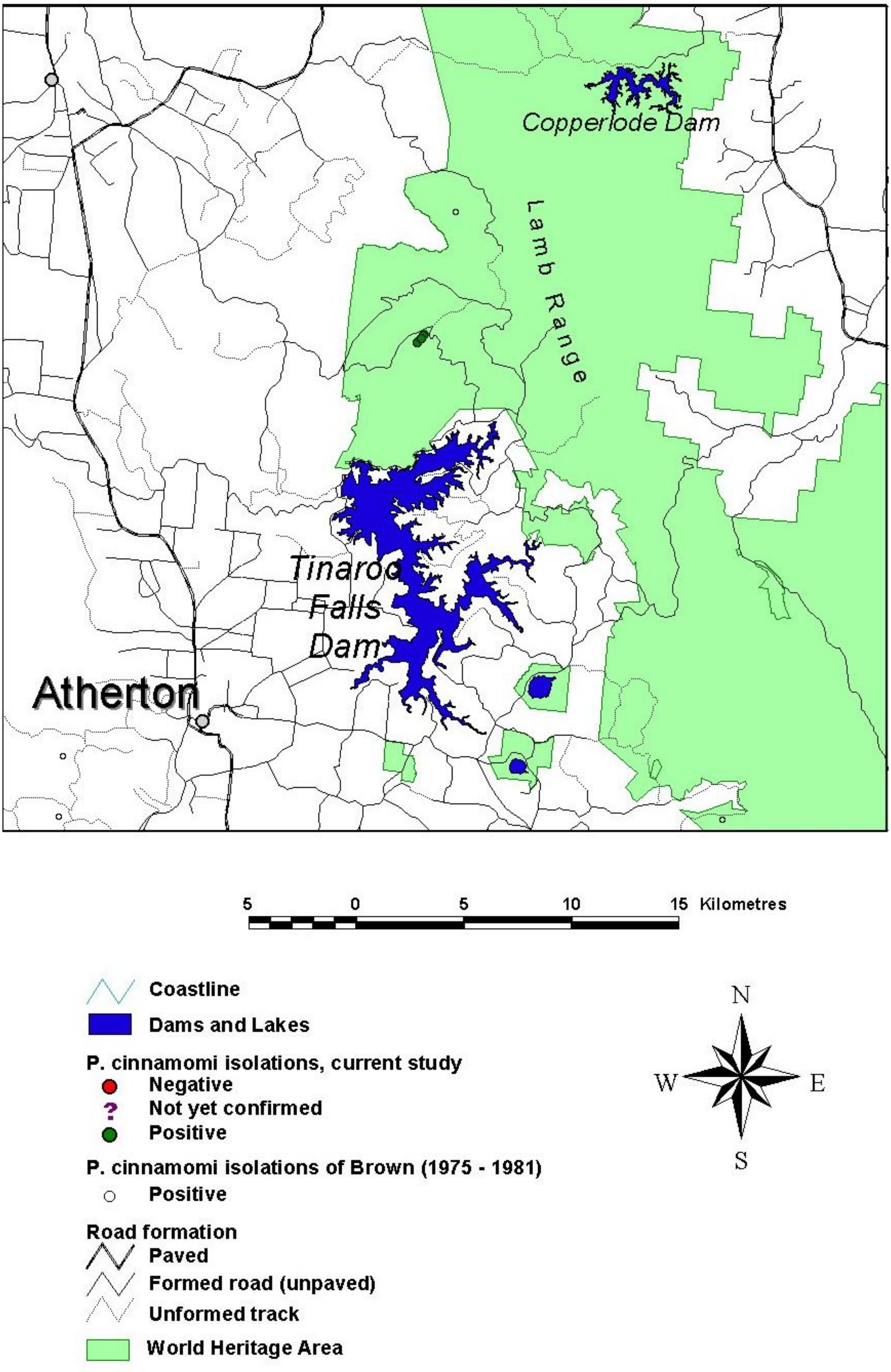


**Figure 4:** *Phytophthora cinnamomi* distribution (Lamb Range study sites).

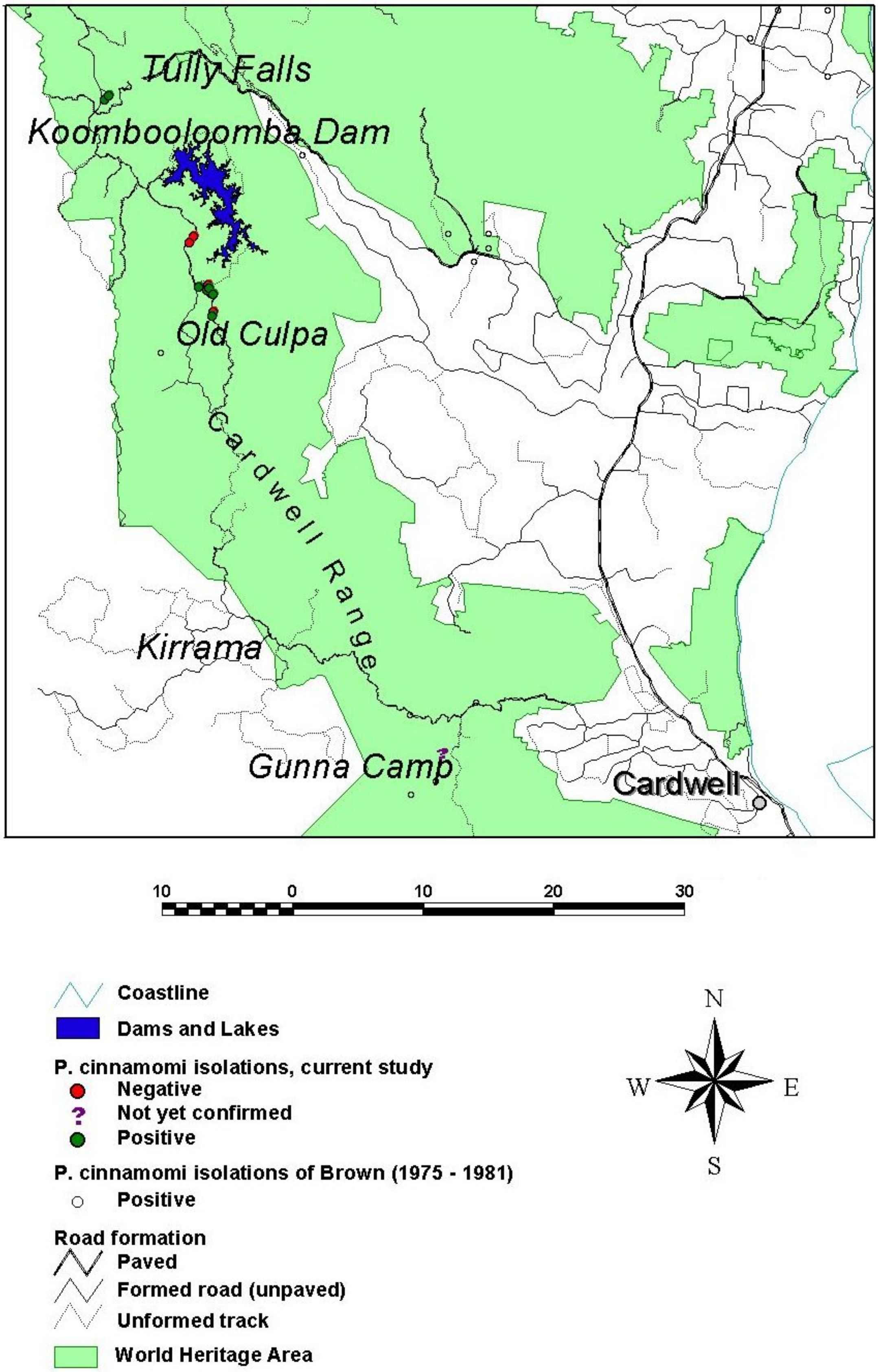


**Figure 5:** *Phytophthora cinnamomi* distribution (southern study sites).

Reports of dieback-like patch death have also come from:

- Mt Bartle Frere western access track;
- Francis Range, near Bartle Frere;
- in eucalypt woodland near Mt Fox, west of Rollingstone; and
- above the overflow of Copperlode Dam, Cairns.

Attempts to isolate *Phytophthora* from creeks in the study areas were unsuccessful.

***Distribution in the landscape***

Despite observations of dieback in along ridgelines along walking tracks in the WTWHA, this does not seem to be a consistent feature (Figure 6). Although a large proportion of polygons were mapped on ridgelines in the Mt Lewis area, in Kirrama, Lamb Range and Koombooloomba/Tully Falls areas, the largest proportion is found along creeks.

Mapped dieback polygons appear to occur at any position in the landscape. The observation of dieback associated with ridgelines is probably an observational bias – the observer is more likely to be travelling a ridgeline than following a creek or traversing a slope, as they provide the easiest route from one point to another. This reinforces the concern of dieback associated with ridgelines, as ridgelines are utilised by potential *Phytophthora* vectors (e.g. bushwalkers, motor vehicles, pigs) for moving around the landscape.

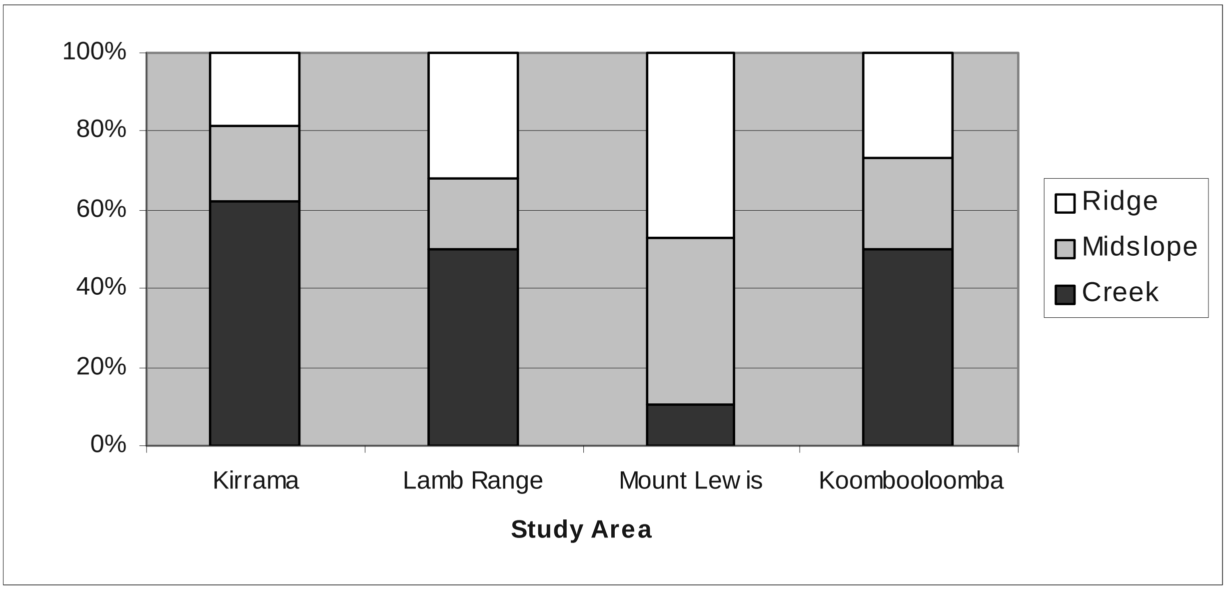


**Figure 6:** Distribution of mapped dieback polygons in the landscape.

## 3.2 REVIEW OF MANAGEMENT LITERATURE

### 3.2.1 The National Threat Abatement Plan – What is it?

The Commonwealth *Environmental Protection and Biodiversity Act 1999* (EPBC Act) took effect in July 2000. Its primary aim is the protection of the Australian environment and biodiversity, including the regulation of actions that may impact on matters of national environmental significance. Of relevance to this discussion, it regulates the Commonwealth's international conservation obligations (including World Heritage Areas and migratory bird habitats), lists threatened species and ecological communities, and provides for the identification of key threatening processes and the preparation of conservation plans.

Under the EPBC Act, "a process is a *threatening process* if it threatens, or may threaten, the survival, abundance or evolutionary development of a native species or ecological community". Currently listed key threatening processes include competition and land degradation caused by rabbits and goats, land clearance, and dieback caused by *P. cinnamomi*. For each key threatening process, a plan must be prepared in order to co-ordinate and focus resources for the abatement of that threat. The Threat Abatement Plan for Dieback Caused by *Phytophthora cinnamomi* ('the Plan') was issued by Environment Australia in draft form in 2000, and in final form in July 2001.

### 3.2.2 Goals of the Plan

The Plan aims to abate threats and thus protect endangered and vulnerable native species and communities by identifying management opportunities and developing a program for co-ordinated implementation of action. It recognises that eradication of *P. cinnamomi* is not possible at present. However, current knowledge can assist in restricting the intensification and spread of known infestations and limit the spread to new sites.

The Plan considers the most serious epidemics "are those that pose identifiable threats of extinction for some... species and ecological communities... Such epidemics are found in... zones south of latitude 30°." Quantifying, monitoring and managing the impact of epidemics requires intensive mapping across large areas. In Western Australia and parts of South Australia, boundary delineation between dieback-affected and unaffected forest is generally straightforward. In Tasmania, a catchment-based approach is used to delineate quarantine areas, rather than monitoring the boundaries of *P. cinnamomi* boundaries.

The Plan gives little mention to the incidence and impacts of *P. cinnamomi* in Queensland, as these outbreaks have been little studied. Although the broadscale distribution of the pathogen is known (Brown 1975, Brown in Gadek, 1999), the reports arising from the current studies represent the first attempts to quantify the pathogen in tropical rainforests, and investigate the diversity of the genus (Abell, 2002, Gadek and Worboys, 2002, Pryce *et. al.* 2002).

Management of *P. cinnamomi*-related dieback is problematic. Diagnosis can be difficult and expensive, and the boundaries between affected and unaffected vegetation amount to thousands of kilometres. The Plan assesses the advantages and disadvantages of various impact mitigation techniques, such as quarantine, hygiene and application of phosphonate fungicide. Even if human-mediated spread of the disease can be effectively managed, there is always the problem of non-human vectors (e.g. pigs, potoroos, bandicoots, echidnas).

There is no clear, universally appropriate action or set of actions for combating the spread of *P. cinnamomi*. A combination of methods is needed that are appropriate to local circumstances, inexpensive and practical for application at the broad scale. Management measures must be applied through co-ordinated partnerships involving landholders, community groups, nursery growers and all levels of government and also integrated with other management activities. In order to target resources for the abatement of the *P. cinnamomi* threat, the Plan lists two primary goals:

- to protect nationally listed threatened species and ecological communities from *P. cinnamomi*; and
- to prevent further species and ecological communities from becoming threatened by exposure to the pathogen.

Objectives arising from these goals are:

- *Management*: To promote the recovery of nationally listed threatened species and ecological communities that are known or perceived to be threatened by *Phytophthora cinnamomi*;
- *Management*: To limit the spread of *Phytophthora cinnamomi* into areas where it may further threaten threatened species and ecological communities or into areas where it may lead to further species or ecological communities becoming threatened;
- *Better Understanding*: To improve the effectiveness and efficiency of the management of the *Phytophthora cinnamomi* through appropriate research and monitoring programs;
- *Education*: To inform Commonwealth, State and Territory management agencies, landholders and the public about the Threat Abatement Plan's actions and their outcomes; and
- *Administration*: To effectively co-ordinate management activities.

### 3.2.3 Policy Issues

***Attitude***

A positive but realistic outlook is necessary when dealing with an ecologically complex problem such as *P. cinnamomi*–related dieback. An attitude of doom and gloom can be a self-fulfilling prophecy if failure to employ control actions leads to spread and intensification of the disease (Shearer and Tippett, 1989).

***Local Landholders***

*P. cinnamomi* has a vast host range (Erwin and Ribeiro 1996). Susceptible horticultural crops, such as avocadoes, macadamias, peaches and pineapples (Cahill, 1993, Erwin and Ribeiro, 1996) have the potential to act as inoculum sources for adjacent protected lands, particularly if the orchards occupy a higher position in the landscape.

***Local Government***

Local government is rarely able to afford the expertise required for the development of *Phytophthora* management plans. In Western Australia, a set of guidelines for managing *Phytophthora*–related dieback has been developed which addresses this problem (Dieback Working Group 2000). The guidelines provide a clear set of objectives and include details on how to develop dieback management plans, how these should be implemented, and who should be responsible for individual tasks.

The guidelines recognise that "it is not practical (or financially feasible) to map *P. cinnamomi* occurrence throughout an entire Local Government area... therefore... the most effective way to manage [it] is by modifying operations that have a high risk of introducing or spreading *Phytophthora* dieback, when these operations are to occur at sites in or adjacent to high value... vegetation."

***State Level***

While guidelines for local government have only recently been developed in Western Australia, a written policy for management of *Phytophthora* on State lands has been in place for over ten years. The need for such a policy is clear – *P. cinnamomi*-related dieback is considered the greatest single threat to conservation values of the south-west (as well as impacting on the long-term viability of the economically and electorally significant jarrah timber industry). The policy was developed by the Department of Conservation and Land Management (CALM, 1991, quoted in Gillen and Napier, 1994). Its stated objectives are:

- to minimise the introduction, spread or intensification of the plant diseases caused by *Phytophthora* species throughout the state, with particular emphasis on the south-west;
- to monitor for *Phytophthora* activity in the remainder of the State, including tropical areas;
- to undertake and support research into the disease and its control; and
- to encourage the West Australian community to share [CALM's] concern over the problem, and its management.

Dieback caused by *P. cinnamomi* is widespread on Kangaroo Island, particularly on the western end of the island. The strategy developed to address the problems consists of seven points (S. Moritz, *pers. comm.*), which are:

- Determine impact of *P. cinnamomi* on threatened species, developing management plans and initiating threat abatement strategies;
- Develop a set of ecological criteria to predict *P. cinnamomi* distribution and spread and potential for infection;
- Map the distribution;
- Determine the effectiveness of phosphonate;
- Implement hygiene strategies in conjunction with stakeholders;
- Work with road managers to mitigate impacts caused by road maintenance; and
- Implement an ongoing management program.

***Commonwealth***

A national approach for managing *Phytophthora* is presented in the Threat Abatement Plan (Environment Australia 2001), discussed above.

### 3.2.4 Dieback Evaluation

***Indicator Species***

Indicator species are considered a valuable tool for *P. cinnamomi*-related dieback evaluation in southern states (Aberton *et. al.* 1999, Dieback Working Group 2000, Wilson *et. al.* 2000). Indicator species are typically plants that are widespread, common, easy to identify, and exhibit spectacular symptoms when affected by *Phytophthora cinnamomi*. This combination of attributes is difficult to find amongst the vast diversity of Australian tropical rainforest canopy trees.

In southern Australia, certain plant species are frequently used as indicator species. Their extreme susceptibility to infection by *P. cinnamomi*, and their associated sudden death after infection, makes them ideal indicators of the infection front. In Western Australia, one such species is *Banksia grandis* (Shearer and Tippett, 1989), and in South Australia and Victoria, *Xanthorrhoea* can play a similar role (Aberton *et. al.* 1999).

***Mapping***

Mapping is an expensive but integral and essential part of Western Australia's *Phytophthora* management program (Shearer and Tippett, 1989). Mapping is undertaken by teams, who ensure a buffered boundary is in place, identify appropriate wash down points for cleaning contaminated machinery (see *Hygiene* in Section 3.2.7) and implement strategies to reduce or prevent access between dieback-affected and unaffected areas.

Victoria has in place mapping procedures for the known distribution of *Phytophthora cinnamomi* isolations, and is using this to develop a workable predictive mapping program.

### *Hazard Rating System*

Western Australia employs a hazard rating system for assessing sites for their susceptibility to *Phytophthora* infection (Shearer and Tippett, 1989). The system considers site factors such as soil, tree species, stand characteristics and climate. The presence of particular species has been found to be a better predictor of hazard than other site attributes.

### *Disease Expression*

Disease expression in Western Australia is rated as low, intermediate or high. These categories are defined by Shearer and Tippett (1989) as:

| | |
|---|---|
| LOW | Symptoms only evident in the shrub layer as a few scattered dead individuals. Understorey and overstorey trees healthy. |
| INTERMEDIATE | Most susceptible understorey species, but less than 10% of overstorey stems dead. Dead overstorey plants are scattered, not clumped. |
| HIGH | Susceptible understorey dead. More than 10% of the overstorey dead. |

### *Selection of Management Areas*

The goal of *Phytophthora* management is to reduce or prevent the pathogen from impacting on susceptible rare and threatened species and ecological communities. If resources are to be directed effectively to this goal, an objective system must be in place to assess the conservation value of managed lands. Barker *et. al.* (1996) list several criteria that were used to prioritise areas for conservation/reservation in a *Phytophthora*-affected region of north-eastern Tasmania. These criteria consider:

- aspects of biodiversity (diversity of rare and threatened species, size of populations, number of populations);
- risk of introduction or further spread of *Phytophthora* infections (position in landscape of existing infections);
- manageability (area, number and length of roads, topography, number of access points); and
- ecological community type.

Barker's approach however was a species-based approach. It sought to identify management areas that would be useful for the long-term conservation of threatened, susceptible species. The procedure first identified areas with natural populations of these species, then ranked them. In the Wet Tropics, such an approach is impractical, given the paucity of knowledge regarding impacts of *P. cinnamomi* on the region's flora, and the lack of information regarding the distribution of many species. Prioritisation of areas according to their overall importance for conservation offers a more useful direction.

Prioritisation of areas for management of *Phytophthora* must use, as its primary criteria, the objectives of the Threat Abatement Plan (Environment Australia 2001). However, not all species and ecological communities that are threatened are currently listed under the EPBC

Act. In the absence of such listings, lists of rare and threatened species and ecological communities supplied in state legislation (e.g. *Queensland Nature Conservation (Wildlife) Regulation 1994*, *Queensland Vegetation Management Regulation 2000*) and local expert knowledge must be relied upon to provide further guidance.

### 3.2.5 Biological Control

***Vector Control***

Any animal that carries soil from dieback-affected areas to unaffected areas is likely to be a vector of *Phytophthora*. Control of non-human vectors, whether native (bandicoots, echidnas, musky rat-kangaroos) or feral (pigs) is difficult, and does not appear to have been attempted.

***Alteration of Fire Regimes***

Manipulation of fire regimes could be used (in fire susceptible communities) to encourage a resistant flora (Hardy *et. al.* 1994, Environment Australia 2001), or to encourage a diverse and antagonistic soil microflora.

***Reduce the Food Base***

In Western Australia, *Banksia grandis* is a prominent understorey tree that is extremely susceptible to infection by *P. cinnamomi*. Attempts to control *P. cinnamomi* by reducing *B. grandis* populations have been unsuccessful.

***Soil Amendments***

Soil amendments have been trialled in an attempt to promote a diverse antagonistic soil microflora. Chicken manure has been found to be an effective suppressant of the symptoms of *Phytophthora* infection, whereas cattle, sheep and horse manure were relatively ineffective (Aryantha *et. al.* 2000). The manipulation of fire regimes to achieve a similar stimulatory effect is discussed above.

A diverse soil microflora is likely to be active in the rich surface soil, whereas *P. cinnamomi* can exploit niches at depth, thus avoiding the antagonistic effects (Shearer and Tippett, 1989).

***Fertilisers***

In Europe, inorganic nitrate fertilisers and other anthropogenic nitrogen inputs have been shown to stimulate sporangial production in *Phytophthora* species (Jung *et. al.* 2000). Nitrate also stimulates fine root growth, bringing about an increase in available host tissue for the pathogen (Thomas Jung, *pers. comm.*).

***Nurseries***

It is imperative that stock for plantation or rehabilitation use is completely *Phytophthora* free, therefore a program of total sanitation and hygiene (see discussion of *Hygeine* in Section 3.2.7) must be implemented in nurseries supplying such stock (Erwin and Ribeiro, 1996).

### 3.2.6 Chemical Control

***Phosphonate***

Neutralised phosphorous acid (phosphite, or more correctly, phosphonate) has been shown to be useful in the suppression of the symptoms of *Phytophthora* infection and slowing of its rate of spread. In cocoa plantations where *Phytophthora palmivora* is endemic, and in avocado plantations affected by *P. cinnamomi*, trunk injected phosphonate has been shown to have long-term control of pod-rot and stem canker, and is more effective than either Ridomil or Aliette (see below) (Guest *et. al.* 1994, Guest *et. al.* 1995). Similar results have been observed in Australian native plants, and phosphonate has been used to protect susceptible species and reduce the rate of spread (Aberton *et. al.* 1999, Ali and Guest, 1998). In Western Australia, it is being used as a last line of defence, protecting remnant populations of a number of critically endangered species from extinction (Hardy *et. al.* 2001). Application is by aerial spraying.

The mode of action is complex, acting both directly on the pathogen and indirectly to enhance the resistance mechanisms of the plant (Guest *et. al.* 1995). It has low toxicity and readily breaks down in the soil. On the down side, phosphonate "does have other effects [on treated plants] that include phytotoxicity, growth abnormalities, reduced reproductive capacity and large difference[s] in levels of *P. cinnamomi* control between plant species" (Hardy *et. al.* 2001). Although the broad mode of action of the chemical suggests that full resistance is unlikely to develop in *P. cinnamomi* (Guest *et. al.* 1995), there is evidence of variation in *in vitro* susceptibility to phosphonate amongst isolates of the pathogen.

It should be emphasised that phosphonate does not eradicate *Phytophthora*, it is merely a suppressant.

#### *Metalaxyl*

Metalaxyl (the active ingredient in Ridomil™ by Ciba Geigy) is a systemic fungicide used in the agricultural control of *Phytophthora.* Although recommended as an eradicant for managed forests and orchards in Italy (Anselmi and Vannini, not dated), it was not effective for this purpose when tested in natural vegetation communities in Western Australia (Hill *et. al.*, 1995).

#### *Phosetyl-Al, Fosetyl –Al*

Phosetyl-Al (the active ingredient in Aliette™ by Aventis) is an alternative formulation of neutralised phosphorous acid, used for the control of *Phytophthora* diseases in agricultural situations. Phytoxicity has been observed at high dosages (Worboys and Middleton, 1991). Aliette's use to protect threatened ecosystems is untested. It releases aluminium upon hydrolysis (Guest *et. al.* 1995), which may have negative impacts on treated plants and soils.

#### *Soil Fumigation*

Soil fumigation in natural environments, using chemicals such as methyl bromide and formaldehyde, or in combination with a host-destroying herbicide treatment, is expensive, dangerous and ultimately ineffective (Erwin and Ribeiro 1996, Hill *et. al.* 1995).

### 3.2.7 Physical Control

#### *Quarantine*

"Access to [unaffected areas] is recognised as being one of, if not the, crucial factor in the artificial spread of the fungus in the south-west of Western Australia and it continues to be a... contentious issue..." (Gillen and Napier, 1994).

Quarantine involves closure of tracks, roads and other areas to all access. It is utilised to protect areas of high conservation value, which have a low chance of infection. In Western Australia, jarrah forest roads have been gated and signed, and track closure has occurred in Stirling Ranges National Park to stop disease spread, while South Australia's National Parks and Wildlife service has closed a section of Morialta Conservation Park to reduce the chance of transfer of *Phytophthora* to unaffected areas (South Australian Department of Environment and Heritage, 2001). Main roads through these areas remain open, despite traversing dieback-affected land. Conservation priority is therefore given to unaffected areas that are physically isolated from infection sources.

Quarantine can be difficult to enforce and requires involvement and education of stakeholders (Environment Australia, 2001). It is unlikely to prevent spread of the disease in the long term (di Stefano, 2001).

***Hygiene***

Implementation of hygiene procedures assumes that the distribution of dieback-affected and unaffected sites is known. Boundary delineation requires regular inspection, regular testing of any disease spread, and assessment of the effectiveness of controls (Environment Australia 2001). In Western Australia, boundary delimitation is generally effective, as the presence of indicator species simplifies the interpretation of affected and unaffected forest areas. Elsewhere in Australia, boundary delineation is not so simple.

Effective hygiene requires the physical separation of affected and unaffected areas. Like quarantine, hygiene is difficult to enforce, it requires careful planning, training, and the implementation of behavioural practices that ensure no contaminated item (such as a grader or a shoe) moves from affected to unaffected areas. Hygiene practices can include:

- the treatment of water used in fire control (Shearer and Tippett, 1989);
- stringent policing of road building (which must be stringently policed), with clear demarcation between affected and unaffected areas (Environment Australia, 2001); and
- educating bushwalkers to clean and disinfect shoes after walking in affected areas (South Australian Department of Environment and Heritage, 2001).

Prevention tactics such as hygiene do not alter the development of the disease once it is established (Shearer and Tippett, 1989).

***Drainage***

Although *Phytophthora* species are aerobic organisms, occasional periods of soil waterlogging facilitate their spread by:

- stressing the plant roots and predisposing them to infection (Burgess *et. al.* 1999); and
- providing a medium through which zoospores can swim from host to host.

Thus, prevention or reduction of waterlogging by improving site drainage can assist plants in escaping infection, even in moderately affected sites.

Improvement of drainage around susceptible plants can be applied at various scales. In Italy, canalisation of flowing water is recommended to reduce spread of *Phytophthora cambivora* (which has a similar biology of infection to *P. cinnamomi*) infection at a forest scale (Anselmi and Vannini, not dated). When rehabilitating bauxite mine sites in Western Australia, it is recommended to plant seedlings on mounds rather than in rills, as mounding facilitates drainage.

### 3.2.8 Education

***Bushwalkers***

One of the prime targets for education campaigns must be bushwalkers. Both Western Australia and South Australian state land management agencies have extensive signage and leaflets, which aim to:

- educate land users about the biology of *Phytophthora* and its spread;
- encourage the use of hygienic bushwalking practices; and
- explain why some areas are quarantined.

Leaflets are illustrated with cartoons and dramatic photographs of dead vegetation, and have attention-grabbing titles like ‘Help Stop the Rot’ or ‘Plant Killer on Kangaroo Island’.

In parks along the southern coast of Western Australia (for example, Stirling Ranges National Park), the Department of CALM have installed large, low, galvanised metal containers. Before commencing their outing, walkers stop at these footwear cleaning stations and use a brush supplied to scrub their boots. South Australia encourages walkers to carry their own hygiene kit, consisting of large and small hard brushes, a bottle of disinfectant (such as methylated spirits or diluted bleach), and a spray bottle. In Tasmania, walkers traversing the Leeaberra Track in Douglas-Apsley National Park are required to walk from *Phytophthora*-free areas in the north to affected areas in the south (Barker *et. al.* 1996).

# 4. DISCUSSION AND RECOMMENDATIONS

## 4.1 GOALS AND CAVEATS

*Phytophthora cinnamomi* is widespread in the WTWHA. Where patch-death of forest has been observed, *P. cinnamomi* has consistently been isolated. However, several other *Phytophthora* species exist in the upland forests of the Wet Tropics, and these too are often found within patch-death sites (Abell, 2002). Whether these too contribute to patch-death, either additively or synergistically, is not known.

Even more perplexing is the observed distribution of *P. cinnamomi* in the Wet Tropics. Although it is widespread and consistently isolated from sites affected by patch death, it is also commonly found in apparently healthy upland and lowland rainforest. Under suitable environmental conditions, *P. cinnamomi* can release vast numbers of swimming zoospores into the soil, and these have the ability to cause disease in a vast range of species (e.g. Weste, 2002, Brown in Gadek, 1999, Podger, 1999, Zentmyer, 1980). However, "it is important to realise that the severity of disease depends not only on a high zoospore inoculum, but on a condusive environment, on the time of exposure to the [zoospore] inoculum, on the degree of host susceptibility and on any environmental stress experienced by the host plant" (Weste, 2002). Patch-death of rainforests is therefore an extreme expression resulting from the presence of the pathogen in soils.

Dobrowolski (1999) has shown a low genetic variability in Australian isolates of the pathogen taken from areas south of 21°S (the latitude of Mackay), providing convincing evidence the species is an introduced organism in these regions. Although not yet confirmed, these findings point to the possibility that *P. cinnamomi* was also introduced into the Wet Tropics, and that distribution in the forests of the Wet Tropics are a consequence of spread by human and other vectors. A precautionary approach is therefore required to minimise risk of its spread, as conservation objectives are served if efforts are made to minimise the impacts of *P. cinnamomi*-related dieback. The recommendations presented in this section reflect this necessity.

In developing recommendations for *Phytophthora*-impact mitigation in the WTWHA, the goals of the Threat Abatement Plan (Environment Australia, 2001) provide the principal direction, and the extensive research conducted in southern Australia provides results which can be applied, with some modification, to the conditions of the Wet Tropics.

The goals and objectives of the Threat Abatement Plan are stated in Section 3.2.2. In addressing these goals it is recognised that:

- further studies of *P. cinnamomi* in the region may show it to be an indigenous species;
- eradication is impossible;
- control of non-human vectors is impossible;
- the pathogen is widespread but not ubiquitous in the soils of the WTWHA, however virulent outbreaks of disease is not expressed in all sites where it is isolated;
- the distribution of the pathogen is inadequately mapped; and
- weather conditions in the WTWHA can create conditions suitable for buildup and spread of inoculum at any time of the year.

## 4.2 MANAGING *PHYTOPHTHERA CINNAMOMI*-RELATED DIEBACK IN THE WTWHA

***Summary***

A *Phytophthora* Dieback Management Strategy involving five steps is proposed here. These steps are:

1. **Develop management plans and initiate threat abatement strategies.**
   List the responsibilities of the Wet Tropics Management Authority and land managers in the WTWHA for driving the implementation of an ongoing *Phytophthora* dieback management program.

2. **Develop a set of ecological criteria to predict *P. cinnamomi* distribution and spread, and potential for infection.**
   In the absence of adequate *P. cinnamomi* mapping in the WTWHA, this provides a set of criteria for identifying areas susceptible to developing *P. cinnamomi*-related dieback, where *Phytophthora* Dieback Management Procedures are to be implemented.

3. **Map the distribution according to the nominated ecological criteria.**
   The recommendations for mapping are based on pre-existing data, and can be implemented without further field work, although additional field data is highly desirable.

4. **Develop *Phytophthora* Dieback Management Procedures.**
   Recommends that hygiene procedures be implemented in works likely to involve soil disturbance.

5. **Implement and monitor *Phytophthora* Dieback Management Procedures in conjunction with land managers.**

The policies, strategies, actions and recommended *Phytophthora* Dieback Management Procedures draw directly, or are adapted from, the work of Kylie Moritz (*pers. comm.* 2001), Barker *et. al.* (1996), the Dieback Working Group (2000) and Environment Australia (2001). The following management recommendations are draft, and should be subject to review in the light of further research outcomes and/or on-the-ground experience.

**Step 1: Develop management plans and initiate threat abatement strategies.**

Table 2 presents policies, strategies and actions to be implemented by the Wet Tropics Management Authority in conjunction with land managers within the WTWHA.

<u>Recommendation:</u> The methods of Dobrowolski (1999) should be applied to *P. cinnamomi* isolates from the Wet Tropics, to determine if the pathogen is highly diverse (suggesting an indigenous pathogen) or whether it has low genetic diversity (suggesting and introduced pathogen). Should outcomes of this work suggest the species is an indigenous pathogen in the Wet Tropics, the recommendations presented in this document will need to be revised.

Surveys of the distribution of *P. cinnamomi* in the WTWHA should be expanded to include walking tracks, particularly those visiting vulnerable mountaintop communities.

**Table 2:** Draft set of policies, strategies and actions to be implemented by the Wet Tropics Management Authority ('the Authority') to manage *P. cinnamomi*-related dieback in the WTWHA.

| Policy | Strategy | Action | Responsible Officer |
|---|---|---|---|
| 1. The Authority formally recognises the significant threat of *Phytophthora*-related dieback to the natural values of the WTWHA | (?) to be provided with appropriate reference material regarding *P. cinnamomi*-related dieback, and attend presentation when appropriate. | • Written material provided to (?).<br>• Presentation regarding *P. cinnamomi*-related dieback made to (?). | To be nominated. |
| | Formal adoption of *P. cinnamomi*-related dieback policies by WTMA. | • WTMA to review reference information.<br>• WTMA to consider advertising for public submissions.<br>• WTMA to endorse the *P. cinnamomi* dieback policy and support the implementation of *Phytophthora* Dieback Management Procedures. | |
| 2. The Authority to consider current activities and procedures, and review these activities and procedures with a view to adopting *Phytophthora* Dieback Management Procedures. | *Phytophthora* Dieback Management Procedures should be implemented into all relevant management operations. | • Consider current operations and procedures and compare with the relevant *Phytophthora* Dieback Management Procedures.<br>• Identify any *Phytophthora* Dieback Management Procedures that may already be in place.<br>• Implement the remaining *Phytophthora* Dieback Management Procedures.<br>• Contractors to be provided with general *Phytophthora* dieback information, and specific instructions regarding changes to 'regular' practices, in accordance with *Phytophthora* Dieback Management Procedures.<br>• Relevant *Phytophthora* Dieback Management Procedures to be included in contracts with all relevant contractors. | |

| Policy | Strategy | Action | Responsible Officer |
|---|---|---|---|
| 3. The Authority to identify catchments of high conservation value and to take action to protect these from introduction of the pathogen. | Catchments of high conservation value in the WTWHA, which are susceptible to *P. cinnamomi*-related dieback should be identified and appropriate steps taken to reduce the likelihood of human introduction of *P. cinnamomi*. | • The following criteria should be used to identify susceptible catchments of high conservation value:<br>1. Susceptibility zone category (High/Moderate/Low), as defined in Section 4.2.2;<br>2. Catchment contains no mapped dieback polygons, or positive *P. cinnamomi* isolations; and<br>3. Catchment ranking, as defined in Section 4.2.2.<br>• Map susceptible catchments.<br>• Prepare and adopt *Phytophthora* dieback management plans for existing activities (e.g. bushwalking).<br>• As a pre-requisite for approval, prepare and adopt *Phytophthora* management plans appropriate to planned activities (e.g. power line construction, road realignments).<br>• Implement relevant *Phytophthora* Dieback Management Procedures. | |
| 4. Relevant land management staff to receive *Phytophthora* management training. | Identify the training needs of appropriate land manager and provide training. | • Identify staff affected by changes in operation as a result of implementing *Phytophthora* Dieback Management Procedures and assess their level of knowledge regarding *Phytophthora* dieback operations. Staff likely to include rangers, work supervisors, work crews, plant operators, etc.<br>• Staff to complete nationally accredited *Phytophthora* dieback training course. | |

| Policy | Strategy | Action | Responsible Officer |
|---|---|---|---|
| 5. Developments and other activities approved by the Authority to contain conditions or recommendations regarding the implementation of *Phytophthora* Dieback Management Procedures. | Applications for activities located within the WTWHA to be approved conditional upon the inclusion of *Phytophthora* Dieback Management Procedures, unless the flow chart in Appendix A indicates otherwise. | • Approval for activities within highly susceptible catchments to include a requirement for the implementation of appropriate *Phytophthora* Dieback Management Procedures. | |
| 6. The Authority to provide information to community conservation groups and other stakeholders to ensure the integrity of land management activities in relation to *Phytophthora* dieback. | Relevant agencies, companies, clubs and groups who use or manage WTWHA land to be provided with appropriate information and details of changes to existing management arrangements. | • Identify agencies, companies, clubs and groups who use or manage lands within or adjacent to the World Heritage Area, and who undertake activities that have the potential to introduce or spread *P. cinnamomi*.<br>• Provide these groups with appropriate information regarding *P. cinnamomi,* and details of any management changes that are required, or management changes that may impact on their activities. | |
| | Agencies, companies, clubs and groups whose activities have a high risk of introducing or spreading *P. cinnamomi* to be provided with general *Phytophthora* dieback information material and encourage to implement *Phytophthora* Dieback Management Procedures. | • Identify large organisations and companies who undertake activities that could introduce or spread *P. cinnamomi* throughout the WTWHA, provide them with general *Phytophthora* dieback information and encourage them to implement the *Phytophthora* Dieback Management Procedures.<br>• Actively promote *Phytophthora* Dieback Management Procedures to WTWHA users.<br>• Ensure that *Phytophthora* dieback information and *Phytophthora* Dieback Management Procedures are easily accessible to WTWHA users. | |

| Policy | Strategy | Action | Responsible Officer |
|---|---|---|---|
| 7. The Authority to regularly review procedures and performance in relation to *Phytophthora* dieback. | Monitor the performance of personnel against training objectives. | • Develop performance measures and assess. | |
| | Monitor success of implementation of *Phytophthora* Dieback Management Procedures. | • Regularly assess work sites to ensure *Phytophthora* Dieback Management Procedures are implemented.<br>• Utilise a standard methodology to assess susceptible catchments to monitor the arrival or further spread of *P. cinnamomi*-related dieback. | |
| | Monitor contractor performance. | • Develop performance measures and assess. | |
| 8. The Authority to review new information and technologies, and include in policy when appropriate. | The Authority to form a "*Phytophthora* Dieback Implementation Group" made up of staff and relevant land managers to discuss and monitor implementation of *Phytophthora* Dieback Management Procedures. | • The "*Phytophthora* Dieback Implementation Group" should meet annually to monitor and review its procedures for the first three years and thereafter as required.<br>• The *Phytophthora* Dieback Implementation Group will consider advances in disease management made by other organisations (e.g. West Australian Department of Conservation and Land Management).<br>• Consider feedback from staff involved in implementing *Phytophthora* Dieback Management Procedures and make the appropriate changes to operations. | |

**Step 2: Develop a set of ecological criteria to predict P. cinnamomi distribution and spread and potential for infection.**

Management of the impacts of *P. cinnamomi*-related dieback requires some knowledge of the distribution of the pathogen. In the absence of detailed knowledge of its distribution, its 'preferred habitat' – areas where patch-death of forest is widespread – must be employed as a surrogate.

This section proposes a set of ecological criteria to predict *P. cinnamomi* distribution and spread, and predicts areas that are likely to express symptoms should they become infected. A flow chart summarising Step 2 is given in Appendix A.

***Susceptibility Zones***

Gadek *et. al.* (2001) noted the three environmental variables most strongly associated with the distribution of mapped dieback polygons were altitude (between 750 metres and 1050 metres), forest type (notophylls dominant) and geology (acid igneous rocks). They also noted associations with shallow slopes, proximity to water courses and proximity to existing and abandoned roads. Dieback was also mapped in other forest communities, and on other rock types, but always within the altitudinal range nominated above.

<u>Recommendation:</u> Utilising existing vegetation and geological mapping data, zones within the WTWHA are to be nominated as having High, Moderate or Low Susceptibility to *P. cinnamomi*-related dieback.

High Susceptibility Zones will have the following criteria: notophylls dominant, an altitude between 750 metres and 1050 metres, located on acid-igneous rocks. Figures 7 to 10 present preliminary maps of the High Susceptibility Zones in the WTWHA based on these criteria[1].

Moderate Susceptibility Zones will have the following criteria: mesophyll rainforests or rainforest with sclerophyll emergents on acid-igneous rocks or basalts or alluvium, between 750 metres and 1050 metres.

Low Susceptibility Zones will have physical characteristics other than those nominated above.

Should additional data on environmental correlates of *P. cinnamomi*-related dieback distribution come to light, these susceptibility criteria are to be reviewed.

[1] GIS layer showing high susceptibility zones prepared by David Gillieson, based upon Webb and Tracey (1975) vegetation mapping and 1:250,000 geological mapping by the Australian Geological Survey Organisation.

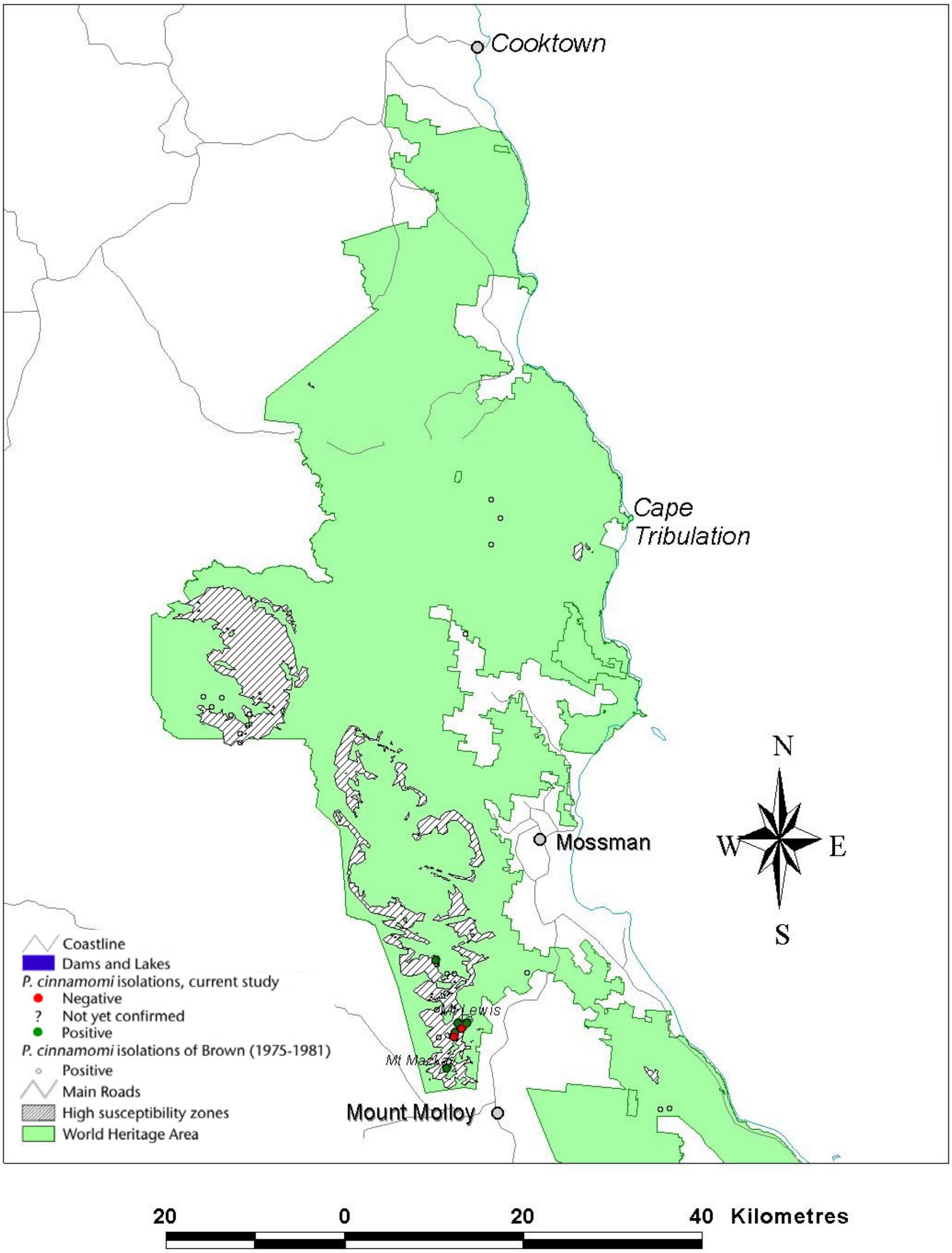


**Figure 7:** Zones of the WTWHA classed as having high susceptibility to *Phytophthora cinnamomi* dieback (Cooktown to Mossman).

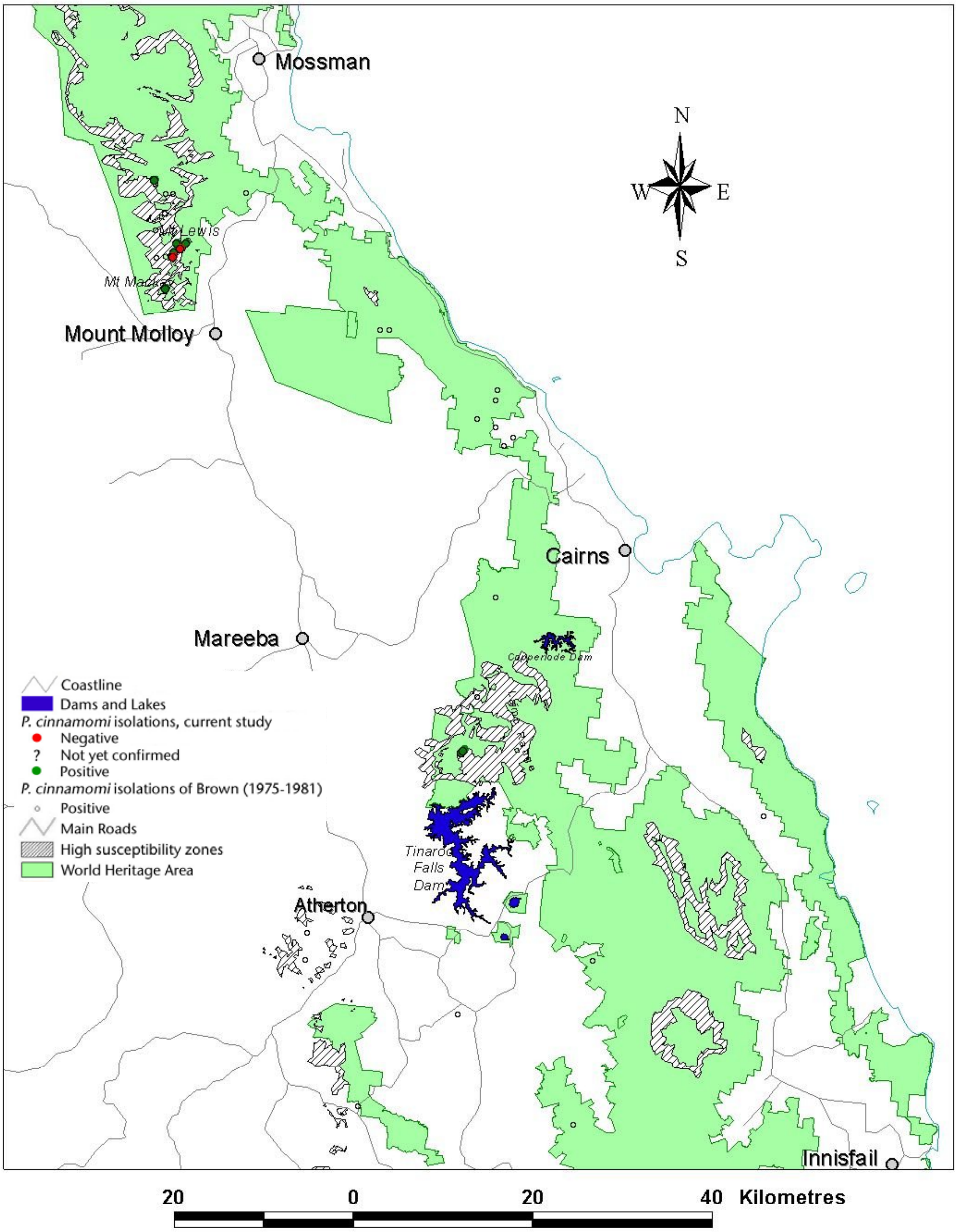


**Figure 8:** Zones of the WTWHA classed as having high susceptibility to *Phytophthora cinnamomi* dieback (Mossman to Innisfail).

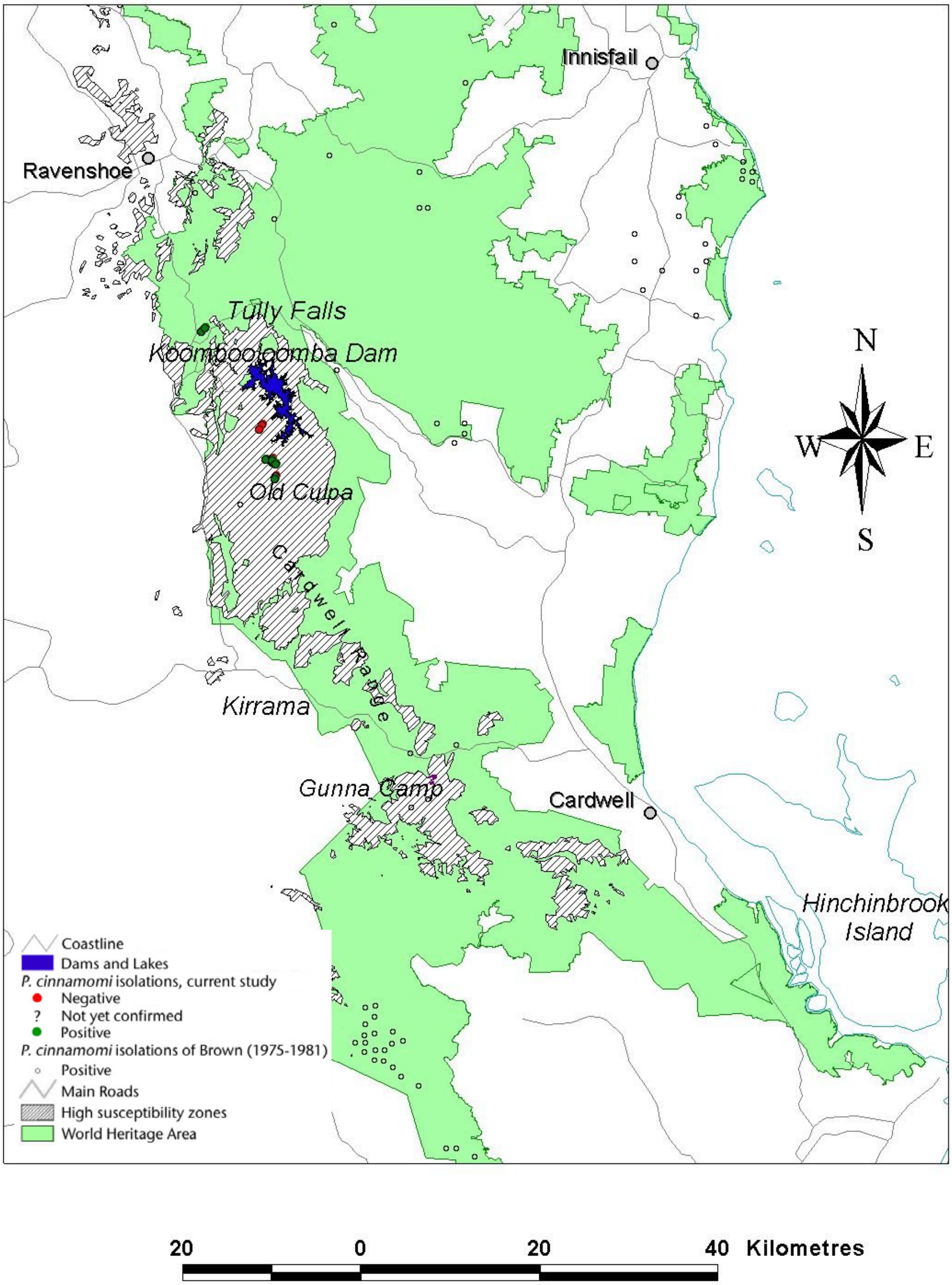


**Figure 9:** Zones of the WTWHA classed as having high susceptibility to *Phytophthora cinnamomi* dieback (Innisfail to Hinchinbrook Island).

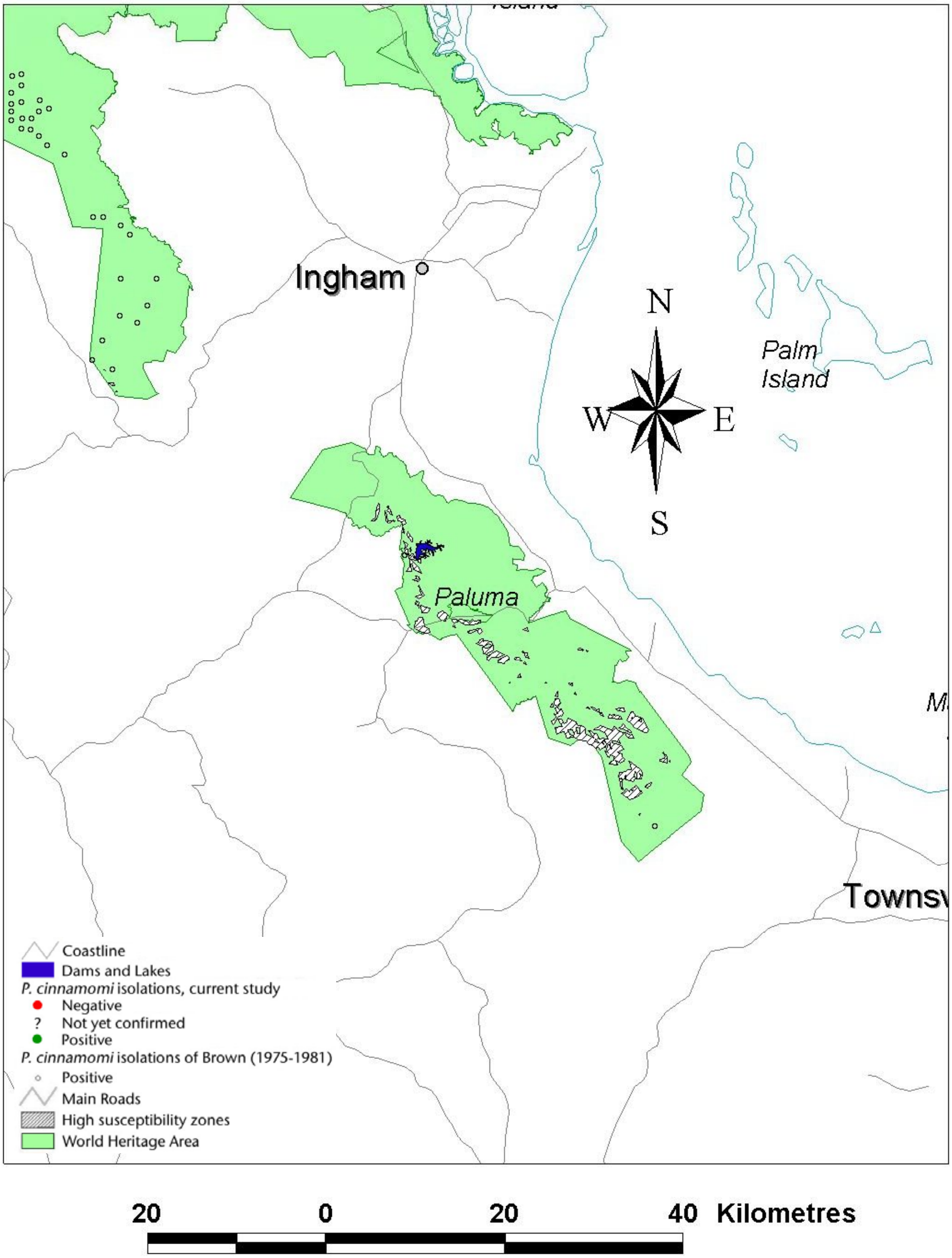


**Figure 10:** Zones of the WTWHA classed as having high susceptibility to *Phytophthora cinnamomi* dieback (Hinchinbrook Island to Townsville).

***Defining Catchments***

The principal goal of dieback management must be to avoid or reduce the chances of introduction by humans of *P. cinnamomi* into *Phytophthora*-free areas. As the direction of natural spread of the pathogen is generally in a downslope direction, a catchment-based approach, similar to that of Barker *et. al.* (1996) is recommended for prioritisation of management areas.

Recommendation: Boundaries of management areas must extend 50 metres downslope from the ridgeline into the adjoining catchment (Barker *et. al.* 1996). Catchments that fall within zones classed as having a High Susceptibility must be ranked first, followed by Moderate Susceptibility and finally Low Susceptibility areas.

The extensive soil sampling of Brown (reported in Brown, 1976 and Brown in Gadek, 1999), found *P. cinnamomi* to be widespread throughout the WTWHA. The locality information, however, is recorded at an accuracy of 1/100 of a degree, implying an error of up to 1.1 km in the mapped points. Thus, although this data is useful for determining broad regional distribution of *P. cinnamomi* in the WTWHA, and establishing its associations with particular vegetation communities and/or lithologies, it is of little use in assessing catchments.

The locations of *P. cinnamomi* sampling sites presented in this document have been recorded with an accuracy of approximately 0.1 kilometre or better, and can be used in determining the infection status of catchments.

Recommendation: It must be assumed that any catchment containing a mapped dieback polygon, or a positive isolation of *P. cinnamomi* (as determined using the methods of Pryce *et. al.* 2002) is infested.

It can also be assumed that, where dieback patches and mapped dieback polygons are observed on ridgelines, both adjoining catchments are infested.

Existing roads through High Susceptibility zones (for example, the Culpa Road or the Mount Lewis Road) are to be assumed to be infested along their entire length. Full hygiene measures need not be implemented in such areas, although wash down and other procedures outlined in Table 6 should be enforced as a matter of routine.

Areas located topographically above confirmed *P. cinnamomi* isolations, and/or areas above mapped dieback polygons, are to be assumed as *Phytophthora*-free, unless soil isolations prove otherwise.

***Ranking Uninfested Catchments***

Management approaches (such as implementation of hygiene measures, road/track closures) can be expensive and controversial. Therefore, a ranking system for management areas is required so that management decisions can be justified and resources can be better directed. Some dieback-affected REs provide significant habitat for threatened species (Sattler and Williams, 1999). If this habitat is seriously impacted by patch death, then significant populations of these species will also be impacted. An example from study sites in the Koombooloomba/Tully Falls area (Gadek and Worboys, 2002) is *Endiandra dichrophylla.* Although observations reveal this species to not be affected by dieback, it is common within forest that was significantly affected by patch death, and therefore in the long term this species may also be impacted.

**Table 3:** Criteria used to rank management areas (adapted from Barker *et. al.* 1996). Higher scores reflect the least preferred condition.

| Criterion[1] | Class | Score |
|---|---|---|
| Conservation Status of Regional Ecosystem covering the catchment. | Endangered<br>Of Concern<br>Not of Concern | 1<br>2<br>3 |
| Wet Tropics Zoning covering the catchment. | Zone A<br>Zone B<br>Zone C | 1<br>2<br>3 |
| Catchment is known to contain plant species listed as rare and threatened under the Commonwealth EPBC Act.[2] | Extinct<br>Critically Endangered<br>Endangered<br>Vulnerable<br>N/A | 1<br>2<br>3<br>4<br>5 |
| Catchment is known to contain plant species listed as rare and threatened under the Queensland Nature Conservation Act, or considered rare by local experts. | Extinct<br>Endangered<br>Vulnerable<br>Rare<br>N/A | 1<br>2<br>3<br>4<br>5 |
| Number of threatened plant species in catchment. | 4, or more<br>3<br>2<br>1<br>0 | 1<br>2<br>3<br>4<br>5 |
| Size of management area.[3] | >1000<br>500-1000<br>100-500<br><100 | 1<br>2<br>3<br>4 |
| Ratio of catchment area to road or track length (includes abandoned logging roads) (ha:km).[4] | 0<br>>100<br>50-100<br>1-50 | 1<br>2<br>3<br>4 |
| Number of access points. | 0<br>1<br>2<br>3<br>>3 | 1<br>2<br>3<br>4<br>5 |
| *P. cinnamomi* isolated from within the catchment? | No<br>Yes | 1<br>2 |
| Is the management area in a part of the landscape located below a confirmed *P. cinnamomi* isolation? | No<br>Yes | 1<br>2 |

[1]If the class for a particular criterion is not known, use the average value for other catchments in the area affected by the proposed activities.

[2]Many rare species in the Wet Tropics are not listed as such under Commonwealth legislation.

[3]These criteria and their respective classes may require further tailoring for the Wet Tropics region.

[4]Many abandoned logging roads are not mapped.

<u>Recommendation:</u> Collate existing dieback records, and determine REs in which they occur. Identify the status of these REs, and ascertain whether *P. cinnamomi* poses a threat to these REs or those downstream.

Utilise local expert knowledge and plant distribution information from the Queensland Herbarium's HERBRECS database to determine the presence of any Rare and Threatened species in the catchments being assessed. The accuracy of the location information in the HERBRECS database is variable, and will need to be taken into account when making these determinations. Collated records are to be used in determining ranking of catchments (see Table 3). Ranking of management areas is to use the criteria listed in Table 3. The higher the ranking score, the lower the priority for conservation and allocation of management resources. High-ranked catchments are likely to have high conservation values, and all measures should be taken to avoid works within them. Catchment ranking should be carried out pro-actively for all streams within the high susceptibility zone.

### *On-Ground Assessment*

A wide range of dieback severities were found within the mapped dieback polygons, from undetectable to spectacularly devastating (see frontispiece). Ground-truthing of mapped dieback polygons is therefore essential for assessing their severity. Long-term monitoring is also lacking in the region – we do not know whether dieback is expanding, contracting or in a 'dynamic equilibrium' in the Wet Tropics environment. Finally, severe dieback has been observed outside the mapped dieback polygons, often associated with walking tracks along ridgelines.

<u>Recommendation:</u> The association of dieback and ridgeline walking tracks, particularly those accessing fragile mountaintop ecosystems, warrants further investigation, and, should an association be found, additional management recommendations will need to be developed.

Continue with dieback monitoring. The level of monitoring is dependent on personnel and resources. At its minimum, the goal of dieback monitoring must be to detect changes in forest structure related to dieback, and is to follow the methodology described in Gadek and Worboys (2002). Therefore, carry out assessments at the central point of existing marked sites, and consider:

- severity of dieback;
- treefall damage; and
- size and health of all trees comprising the canopy and subcanopy above the plot, including size and health of indicator species (Table 4).

Should resources be available, the goals of dieback monitoring should be to detect changes in forest structure, canopy openness and canopy floristics related to dieback. Therefore, assessments should cover the points listed above, and also include:

- an assessment of canopy openness;
- an assessment of canopy floristics;
- significant expansion of the ground-truthing of mapped dieback polygons; and
- investigation of reports of dieback patches outside of the currently mapped areas.

Based on the stem counts and tree health observations collected during this project, several species may be useful as indicator species (Table 4). I believe the first four species in the table are of more use than the latter four, as I have found them both more common and far easier to identify in the field.

**Table 4:** Canopy tree species with potential use as indicators of dieback severity.

| Species | Number of Stems | Average Health |
|---|---|---|
| *Flindersia bourjotiana* | 155 | 1.30 |
| *Cryptocarya mackinnoniana* | 85 | 1.37 |
| *Cardwellia sublimis* | 49 | 1.45 |
| *Franciscodendron laurifolium* | 58 | 1.22 |
| *Elaeocarpus sericopetalus* | 27 | 2.07 |
| *Endiandra bessaphila* | 29 | 1.72 |
| *Sloanea australis ssp. parviflora* | 23 | 1.61 |
| *Beilschmiedia tooram* | 31 | 1.29 |

### Step 3: Mapping Susceptible Catchments

The goal of mapping is to determine areas where:

- a high ranking indicates the presence of threatened species or ecological communities that are likely to prevent or affect planning of management or other activities; and
- hygiene measures should be incorporated into any activities which could lead to the introduction and/or spread of *P. cinnamomi*.

In all dieback management protocols, mapping of dieback plays an important role in developing management strategies. However, given the wide distribution of *P. cinnamomi* in soils of the Wet Tropics, the difficulty of the terrain and the size of the area concerned, the ground-truthing required for adequate mapping makes this exercise impractical at this point in time. Therefore, areas of the WTWHA with the dieback correlates described above are to be treated as high-susceptibility areas for future development works. Such areas are mapped at low scale in Figure 10 of Gadek *et. al.* (2001), and occupy some 14% of the World Heritage Area. Existing roads and high-use short walking tracks should be exempted from consideration as high-susceptibility *Phytophthora*-free areas.

<u>Recommendation:</u> Mapping of High Susceptibility areas has been completed at a broad scale (Figure 10, Gadek *et. al.* 2001). Before any new works take place in this High Susceptibility area, ranking of catchments to be affected by the proposed works is to be carried out, following the criteria listed in Table 3. Ranking of catchments will facilitate decisions regarding:

- placement of linear corridors (such as walking tracks); and
- placement of point facilities (such as transmission towers or power transmission pylons) and their access tracks.

### Step 4: Develop *Phytophthora* Dieback Management Procedures

The most effective way to manage the pathogen is by modifying operations that have a high susceptibility to introducing or spreading *P. cinnamomi*-related dieback, when these operations are judged to occur in High Susceptibility zones, or dieback-affected Moderate or Low Susceptibility zones. In most cases, modifying the operation should not require a significant increase in time or costs. Forward planning and some flexibility in works programming will ensure that modifications can occur with minimal inconvenience.

The following are activities occurring in the WTHWA that have a moderate to high risk of introducing or spreading *P. cinnamomi* to catchments that are currently uninfested:

- construction and maintenance infrastructure, such as roads, drains, toilets, or walking tracks, and associated rehabilitation;
- environmental maintenance (slashing, weed control, track maintenance);
- fire-fighting activities; and
- bushwalking.

The following series of tables list *Phytophthora* Dieback Management Procedures, which must be implemented to reduce the risk of introduction of *P. cinnamomi* by these activities. Decisions on the *Phytophthora* Dieback Management Procedures to be implemented are to be made with reference to flow chart (Appendix A).

**Step 5: Implementation**

Implement the *Phytophthora* Dieback Management Procedures.

**Table 5:** *Phytophthora* Dieback Management Procedures for infrastructure construction and maintenance in *Phytophthora*-free areas.

| | |
|---|---|
| **PLANNING PHASE** | • Map the location of the planned activities, and determine the level of *Phytophthora* Dieback Management Procedures to be implemented using the flow chart in Appendix A.<br>• For catchments that are *P. cinnamomi*-free, the works plan is to incorporate the following *Phytophthora* Dieback Management Procedures. |
| **TIMING** | • Activities to be planned for the dry season, and postponed during and following rainfall. |
| **MATERIALS** | • Gravel, soil or sand brought onto the site is to be free of *P. cinnamomi.* If the planned activities involve the supply of a significant amount of materials, it may be more cost effective to survey the site for *P. cinnamomi* first to confirm the site isn't already infested. If a site is infested, then the materials do not need to be free of *P. cinnamomi*.<br>• Stockpile topsoil and return it to the site in preference to importing fill.<br>• Imported pipes, stone pitching materials and other construction materials to be free of mud and soil. |
| **PROCEDURES** | • Stay within the construction zone.<br>• If moving into forest on foot, footwear is to be free of mud and soil. If it is necessary to leave the catchment, implement the *Phytophthora* Dieback Management Procedures for bushwalking.<br>• Store gravel and other materials at the work site on a hard, dry, well-drained surface that drains into the impacted catchment.<br>• When grading:<br>- grade from upslope to downslope (when applicable);<br>- grading equipment is to be clean before commencing work;<br>- the angle of the grader blade is to be adjusted to avoid carrying soil/gravel long distances; and<br>- do not grade wider than prescribed. |
| **VEHICLES AND MACHINERY** | • Vehicles, machinery and equipment to be free of mud and soil when:<br>- transporting gravel and other construction materials;<br>- arriving at a site; and<br>- when moving to an uninfested catchment.<br>*(There will be a reduced need for cleaning if the operation is completed in dry soil conditions)*<br>• If cleaning is to occur in the field:<br>- select a hard, well drained surface (e.g. road), well away from vegetation;<br>- wash down in the area in which the activities have occurred;<br>- one side of the wash down area is assumed to be infested, the other, uninfested. Operations on either side of the boundary are to be kept separate; and<br>- minimise the use of water, and attempt to remove mud and soil with a brush or stick.<br>• Park vehicles and machinery on cleared land. |
| **SOIL MOVEMENT** | • Soil, gravel and plant material removed from any site should not be used in uninfested catchments. |
| **WATER** | • Town water, bore water or sterilised water to be used. |

| | |
|---|---|
| **REHABILITATION** | • Rehabilitate site with *P. cinnamomi* resistant species appropriate to the local area. A preliminary list of resistant species is provided in Appendix B.<br>• Revegetation has a high probability of introducing *P. cinnamomi*, particularly as it needs to occur during or immediately before the Wet Season, therefore:<br>- consider direct seeding rather than planting seedlings;<br>- obtain plants from a nursery with accredited hygiene procedures under the Australian Nursery Industry Accreditation Scheme;<br>- ensure all machinery, tools and equipment are free of mud and soil when commencing works in a new catchment, and are cleaned prior to finishing or moving to another catchment; and<br>- if using mulch, ensure that it has been sourced on site, or has been well composted (the heating part of the composting process kills *P. cinnamomi*). |
| **STAFF** | • Staff and contractor involved in road and drain construction and maintenance activities to receive training in *Phytophthora* dieback management.<br>• *Phytophthora* dieback information to be include in field staff induction process. |

**Table 6:** *Phytophthora* Dieback Management Procedures for infrastructure construction and maintenance areas where all catchments are assumed to be infested (e.g. Culpa Road, Mt Lewis Road, access track to the head of Tully Falls).

| | |
|---|---|
| **PLANNING PHASE** | • Map the location of the planned activities, and determine the level of *Phytophthora* Dieback Management Procedures to be implemented using flow chart in Appendix A.<br>• For activities that are undertaken entirely within infested catchments, the works plan is to incorporate the following *Phytophthora* Dieback Management Procedures. |
| **TIMING** | • Activities at *P. cinnamomi*-free sites should be scheduled for dry soil conditions before undertaking works in infested areas. |
| **MATERIALS** | • The use of materials that are free of *P. cinnamomi* is encouraged, but this is not essential.<br>• *P. cinnamomi*–free materials should be used at uninfested sites before infested sites. |
| **PROCEDURES** | • Stay within the construction zone.<br>• If moving into forest on foot, footwear is to be free of mud and soil. If it is necessary to leave the catchment, implement the *Phytophthora* Dieback Management Procedures for bushwalking.<br>• Store gravel and other materials at the work site on a hard, dry, well-drained surface that drains into the impacted catchment. |
| **VEHICLES AND MACHINERY** | • Vehicles, machinery and equipment to be free of mud and soil when leaving the site. *(There will be a reduced need for cleaning if the operation is completed in dry soil conditions)*<br>• If cleaning is to occur in the field:<br>- select a hard, well drained surface (e.g. road), well away from vegetation;<br>- wash down in the area in which the activities have occurred;<br>- one side of the wash down area is assumed to be infested, the other, uninfested. Operations on either side of the boundary are to be kept separate; and<br>- minimise the use of water, and attempt to remove mud and soil with a brush or stick.<br>• Park vehicles and machinery on cleared land. |
| **REHABILITATION** | • Rehabilitate site with *P. cinnamomi* resistant species appropriate to the local area. A preliminary list of resistant species is provided in Appendix B.<br>• Revegetation has a high probability of introducing *P. cinnamomi*, particularly as it needs to occur during or immediately before the Wet Season, therefore:<br>- consider direct seeding rather than planting seedlings;<br>- obtain plants from a nursery with accredited hygiene procedures under the Australian Nursery Industry Accreditation Scheme;<br>- ensure all machinery, tools and equipment are free of mud and soil when commencing works in a new catchment, and are cleaned prior to finishing or moving to another catchment; and<br>- if using mulch, ensure that it has been sourced on site, or has been well composted (the heating part of the composting process kills *P. cinnamomi*). |
| **STAFF** | • Staff and contractor involved in road and drain construction and maintenance activities to receive training in *Phytophthora* dieback management.<br>• *Phytophthora* dieback information to be include in field staff induction process. |

**Table 7:** *Phytophthora* Dieback Management Procedures for environmental maintenance activities in *P. cinnamomi*-free areas.

| | |
|---|---|
| **TIMING** | • Activities such as slashing, removal of woody weeds, etc. to occur in dry soil conditions. |
| **REHABILITATION** | • Rehabilitate sites with *P. cinnamomi* resistant species appropriate to the local area. A preliminary list of resistant species is provided in Appendix B.<br>• Revegetation has a high probability of introducing *P. cinnamomi*, particularly as it needs to occur during or immediately before the Wet Season, therefore:<br>- consider direct seeding rather than planting seedlings;<br>- obtain plants from a nursery with accredited hygiene procedures under the Australian Nursery Industry Accreditation Scheme;<br>- ensure all machinery, tools and equipment are free of mud and soil when commencing works in a new catchment, and are cleaned prior to finishing or moving to another catchment; and<br>- if using mulch, ensure that it has been sourced on site, or has been well composted (the heating part of the composting process kills *P. cinnamomi*). |
| **ACCESS** | • Off road vehicles, motorcycles and horses to be kept to established roads and trails, which are likely to already be infested.<br>• Minimise the number of tracks in unaffected catchments, and ensure they have hard, dry, well-drained surfaces.<br>• When constructing tracks:<br>- construct in dry soil conditions;<br>- map catchments to be impacted by the proposed track – the track should not pass from infested catchments to *P. cinnamomi*-free catchments;<br>- if tracks are to be constructed in *P. cinnamomi*-free catchments, implement full hygiene procedures, as outlined in Table 5;<br>- consider construction of wooden walkways over muddy areas; and<br>- ensure materials that can be used to construct tracks include *P. cinnamomi*-free gravel, concrete, and limestone. |
| **SOIL MOVEMENT** | • Minimise soils disturbance, for example, mow, slash or use herbicide to control weeds and keep open drains, rather than grade or plough.<br>• If soil, gravel, sand, river stones, etc. are to be imported into bushland reserves, these materials are to be free of *P. cinnamomi*. |
| **VEHICLES, MACHINERY & TOOLS** | • All machinery and vehicles to be free of mud and soils on tyres, mudflaps, body and underbody when entering a *P. cinnamomi*-free catchment. As a matter of routine, all machinery and vehicles to be washed down prior to leaving.<br>• All tools and equipment to be free of mud and soil when entering *P. cinnamomi*-free catchment. As a matter of routine, all tools and equipment are to be washed down prior to removal. |
| **WATER** | • Town water, bore water of sterilised water to be used. |
| **COMMUNICATION AND EDUCATION** | • An ongoing commitment to visitor education is essential. *P. cinnamomi* awareness to be an integral part of signage and interpretive displays within the High Susceptibility zones of the WTWHA.<br>• Provide information to stakeholder groups, such as bushwalking clubs, conservation groups, ecotourism operators, etc.<br>• In High Susceptibility zones of the WTWHA, place signage to recommend avoiding access when soil is muddy (could also highlight that leech abundance is correlated with soil moisture, as an additional deterrent!) and that visitors to keep to tracks. |

| | |
|---|---|
| **ROADSIDE MAINTENANCE** | • Slashers, tractors and other equipment used on roadsides to be washed down daily, as a matter of routine, when operating in the High Susceptibility zone. |
| **STAFF** | • Land Managers and contractors involved in construction and maintenance activities to receive training in *Phytophthora* Dieback Management Procedures. |

**Table 8:** *Phytophthora* Dieback Management Procedures for bushwalking and other recreational activities within the High Susceptibility zone.

| | |
|---|---|
| **TIMING** | • Bushwalking activities in the High Susceptibility Zone preferably to occur in dry soil conditions. |
| **COMMUNICATION AND EDUCATON** | • An ongoing commitment to visitor education is essential. *P. cinnamomi* awareness to be an integral part of signage and interpretive displays within the High Susceptibility zones of the WTWHA.<br>• Provide information to stakeholder groups, such as bushwalking clubs, conservation groups, ecotourism operators, etc.<br>• In High Susceptibility zones of the WTWHA, place signage to recommend avoiding access when soil is muddy and recommend visitors to keep to tracks. |
| **ACCESS** | • Consideration should be given to restricting access to walking tracks in the High Susceptibility zone during the wet season, or at least those which traverse *P. cinnamomi*-free catchments.<br>• If a walking track traverses both *P. cinnamomi*-free catchments and infested catchments, walkers should be directed to commence the walk (with clean boots) in the *P. cinnamomi*-free areas, before moving into infested catchments. |
| **SOIL MOVEMENTS** | • Reduce the likelihood of transporting soil between infested and uninfested catchments by:<br>- educating walkers by appropriate signage;<br>- installing signposted clean-down points at appropriate points on the track (including the start of the track); and<br>- encouraging walkers to carry a hard brush and bottle of methylated spirits to use in cleaning and disinfecting boots. |

**Table 9:** *Phytophthora* Dieback Management Procedures for fire management activities within the High Susceptibility zone.

| | |
|---|---|
| **HYGIENE** | • Machinery, vehicles and equipment to arrive at site free of mud and soil:<br>- to clean machinery, use a brush, spade, bar or compressed air in preference to washing down with water;<br>- wash down at designated wash down points or on a hard, well-drained surface that does not run off into forest.<br>- clean machinery, vehicles and equipment before moving to another area.<br>• If you know the *Phytophthora* dieback status of the area, do not move from infested to uninfested areas unless the vehicle, machinery and equipment are free of soil and mud. |
| **FIRE BREAKS** | • Procedures for construction and maintenance of fire breaks to follow procedures listed for road construction and maintenance (Tables 5 and 6). The level of *Phytophthora* Dieback Management Procedures to be implemented to be determined with reference to Appendix A. |
| **FIRE SUPPRESSION** | • Use hand tools to suppress the fire where this method will succeed.<br>• Use machinery only when necessary.<br>• Use scheme or bore water for fire suppression whenever possible. |
| **TRAINING** | • Training and practice sessions should not occur in, or adjacent to, bushland areas or horticultural crops in wet soil conditions.<br>• *Phytophthora* dieback information to be included in induction process for new crewmembers. |

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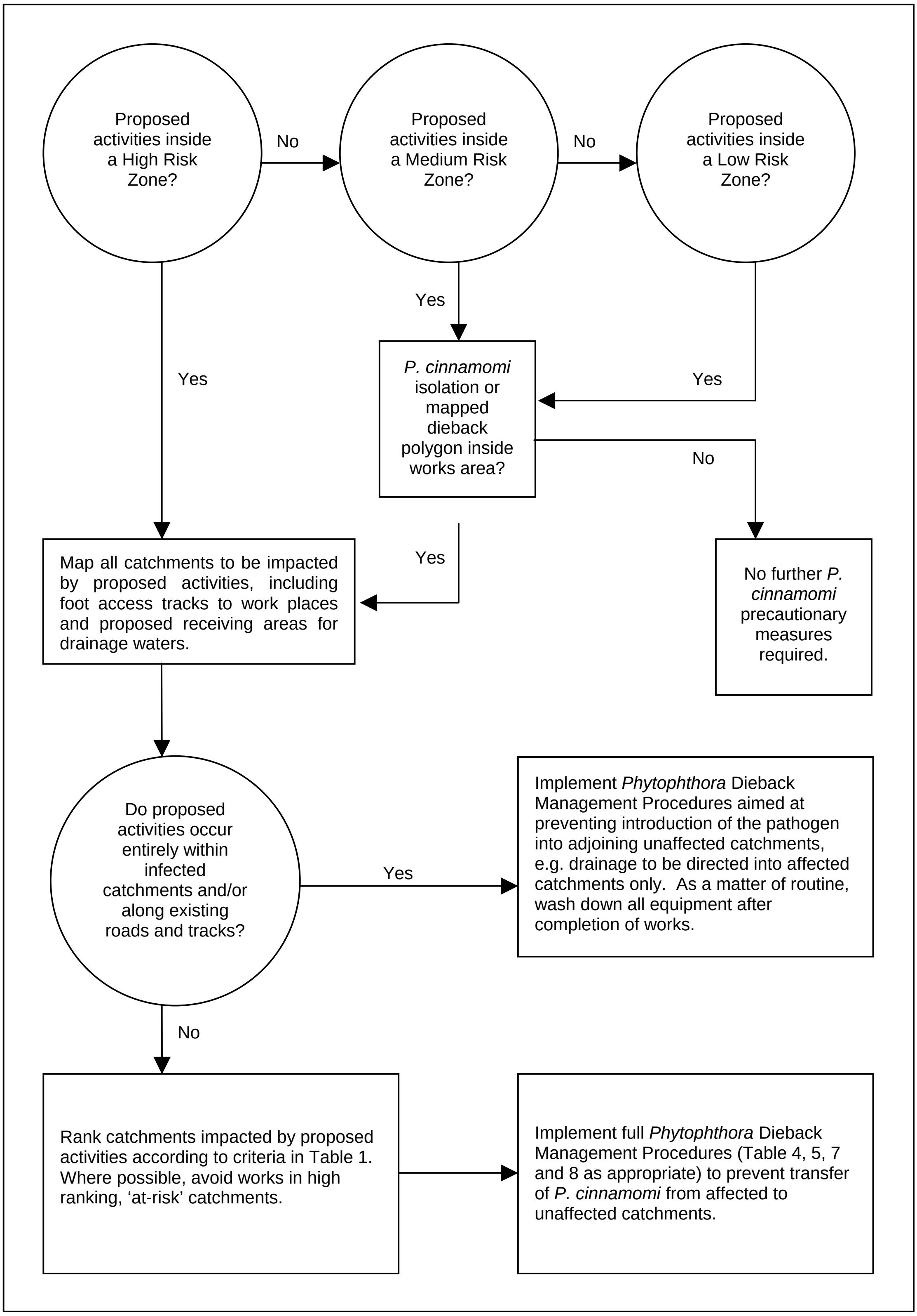
# APPENDIX A

Flow chart for determining requirements for implementation of *Phytophthora* Dieback Management Procedures.



# APPENDIX B

Preliminary list of species that persist in a visibly healthy condition on dieback affected sites (determined from the data of Gadek and Worboys, 2002). Persistent species were defined as those species with five or more stems occurring on dieback affected sites, with none of these stems displaying any symptoms of dieback. No testing of resistance under laboratory conditions has been carried out, nor do we know if they will succumb in the future. These species are recommended for use in rehabilitation of disturbed areas in the high susceptibility zone (if available).

| | |
|---|---|
| Aquifoliaceae | *Sphenostemon lobosporus* |
| Araliaceae | *Polyscias australiana* |
| Clusiaceae | *Garcinia sp. (Davies Creek J.G. Tracey 14745)* |
| Cunoniaceae | *Ceratopetalum succirubrum* |
| Cunoniaceae | *Pullea stutzeri* |
| Cyatheaceae | *Cyathea cooperi* |
| Elaeocarpaceae | *Elaeocarpus eumundi* |
| Euphorbiaceae | *Antidesma erostre* |
| Euphorbiaceae | *Hylandia dockrillii* |
| Grossulariaceae | *Polyosma alangiacea* |
| Icacinaceae | *Apodytes brachystylis* |
| Icacinaceae | *Citronella smythii* |
| Icacinaceae | *Irvingbaileya australis* |
| Lamiaceae | *Gmelina fasciculiflora* |
| Lauraceae | *Cryptocarya angulata* |
| Lauraceae | *Cryptocarya densiflora* |
| Lauraceae | *Cryptocarya lividula* |
| Lauraceae | *Cryptocarya putida* |
| Lauraceae | *Endiandra dichrophylla* |
| Lauraceae | *Endiandra monothyra ssp. monothyra* |
| Lauraceae | *Endiandra sankeyana* |
| Meliaceae | *Synoum muelleri* |
| Monimiaceae | *Daphnandra repandula* |
| Myrtaceae | *Acmena resa* |
| Myrtaceae | *Austromyrtus sp. (Gillies BG 1484)* |
| Myrtaceae | *Rhodamnia sessiliflora* |
| Myrtaceae | *Syzygium cormiflorum* |
| Myrtaceae | *Syzygium johnsonii* |
| Myrtaceae | *Waterhousea unipunctata* |
| Ochnaceae | *Brackenridgea australiana* |
| Oleaceae | *Chionanthus axillaris* |
| Proteaceae | *Stenocarpus sinuatus* |

| | |
|---|---|
| Rubiaceae | *Atractocarpus fitzalanii ssp. tenuipes* |
| Rutaceae | *Brombya platynema* |
| Rutaceae | *Flindersia pimenteliana* |
| Rutaceae | *Melicope elleryana* |
| Sapindaceae | *Mischocarpus macrocarpus* |
| Sapotaceae | *Pouteria euphlebia* |
| Sapotaceae | *Pouteria papyracea* |
| Symplocaceae | *Symplocos cochinchinensis var. gittonsii* |
| Winteraceae | *Bubbia semecarpoides* |