Best Practice Management Guidelines for *Phytophthora cinnamomi* within the Sydney Metropolitan Catchment Management Authority Area.

By
Therese Suddaby and Edward Liew
Botanic Gardens Trust
Royal Botanic Gardens Sydney
Mrs Macquaries Road, Sydney, NSW 2000

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SECTION 1: INTRODUCTION

1.1 Background

Phytophthora cinnamomi is a microscopic organism that lives in soils and plant roots and is the key organism associated with dieback of native plant species in Australia. *P. cinnamomi* occurs in all states and territories on a broad range of commercial crop plants and native plant species.

In February 2007, the Botanic Gardens Trust (BGT) Division of Department of Environment and Climate Change (DECC) was contracted and funded by the Sydney Metropolitan Catchment Management Authority (SMCMA) to commence the project titled 'Survey and management of *Phytophthora cinnamomi* within the Sydney Metropolitan Catchment Management Authority area'.

The three principle activities of the project were to:

1. Conduct surveys and collate data from previous surveys for the presence of *P. cinnamomi* and dieback disease by taking soil samples
2. Test the susceptibility of targeted plant species under controlled inoculation and environmental conditions
3. Develop *P. cinnamomi* awareness material and Best Practice Management Guidelines to raise awareness of actions to prevent the spread of *P. cinnamomi.*

This document contains the Best Practice Management Guidelines developed in response to the survey and the susceptibility trials conducted by the Royal Botanic Gardens (RBG), Sydney, for the SMCMA area. These guidelines will assist in the protection of ecological communities that may be at risk as a consequence of dieback disease. Whilst recognising that other Best Practice Management Guidelines are available *for P. cinnamomi*, this document seeks to provide information that is most relevant to eastern New South Wales (NSW). These guidelines present a precautionary approach to land management in areas vulnerable to *Phytophthora* dieback. Hence this document is particularly targeted towards land managers (national park officers, council officers and environmental managers) to assist in decision-making processes pertaining to management of native ecosystems. As knowledge about the distribution and impact of *P. cinnamomi* within the SMCMA area improves, it will be possible to specifically target hygiene and disease control measures. Until then, following these guidelines will contribute to the abatement of the threat of *P. cinnamomi* and will also reduce the risk of spread of other pathogens and invasive plants within the catchment.

1.2 *Phytophthora cinnamomi*

1.2.1 Description of pathogen

Phytophthora cinnamomi, commonly known as “root rot pathogen”, is a microscopic organism that lives in soils and plant roots. Infection of plants by *P. cinnamomi* begins by invasion of the roots, and in some cases the stem and storage tissues. Following infection, lesions develop and the root tissue becomes necrotic and starts to rot. In susceptible species, the phloem and cambium of the root are also invaded, resulting in failure of the vascular system. The presence of *P. cinnamomi* is often first realised only when secondary symptoms develop above ground as a result of root rot. These secondary symptoms resemble those of drought and include wilt, chlorosis (yellowing) of leaves, poor crown development, dieback of major branches, stunted growth and shallow root systems. The relationship between these observed dieback symptoms and *P. cinnamomi* was only recently confirmed in 2000.

Some plant species take longer to succumb to *P. cinnamomi* than others. Susceptible plants may die suddenly within weeks or death may take over three years, such as in *Eucalyptus marginata.* Other plants display symptoms of dieback in conditions conducive to disease but recover again as conditions become less suitable for the pathogen. Susceptible woody shrubs are killed by decay of the entire root system. Foliage of woody shrubs becomes chlorotic (yellowing), then necrotic (rotting), followed by collapse of the entire plant. Branches of larger trees dieback and eventually the entire plant will die. Larger trees may also die even if only a part of the root system is infected, as invasion by the pathogen results in a failure in hydraulic conductance throughout the root system. Herbaceous plants frequently exhibit wilt and chlorosis. Species regarded as tolerant show moderate dieback of branches in periods of environmental stress but do not die. Field resistant species show no symptoms, even though they may be infection.

In nature, the expression of disease for a given plant species can be variable because environmental conditions influence the development of disease. Disease epidemiology of *P. cinnamomi* induced dieback is complex and dependent on a number of biotic and abiotic factors including climate, soil characteristics, soil microbes and host physiology and susceptibility. Pathogen activity is largely influenced by seasonal patterns in temperature and rainfall. *P. cinnamomi* activity is favoured by mild temperatures and high rainfall (greater than 600 mm annually), however the onset of above ground symptoms may not occur until drought conditions prevail upon the stressed root system. As a result, *P. cinnamomi* has been particularly successful in areas of Australia with a Mediterranean climate.

Phytophthora species spread by producing motile zoospores which can swim small distances and infect new hosts. These spores are released when there is free water available and soil temperatures are greater than 12°C. The pathogen can spread autonomously, up to a few metres per year via zoospores or by mycelial growth if root to root contact occurs. In addition to the highly infective zoospore, *P. cinnamomi* also produces a hard walled chlamydospore which can survive in the soil or dead root tissues for many months or possibly years.

Any process that involves the movement of infested soil or plant root material will contribute to the spread of disease through the movement of spores. Passive dispersal of the pathogen occurs via surface and sub-surface water runoff down slopes and drainage lines. Long distance spread of the disease is facilitated by human activities such as bushwalking, horse riding, bike riding, 4WD, mining and forestry operations, earthmoving and construction.

P. cinnamomi survives within the live root tissues of infected hosts and cannot be eradicated from the soil or the roots of infected plants under natural conditions.

1.2.2 Distribution

It is likely that *P. cinnamomi* was introduced into the Sydney region of NSW soon after European settlement. Over the past 60 years, dieback symptoms have been detected and identified in natural vegetation communities in various areas within NSW and is believed to be widely distributed. Dieback has been identified within Barrington Tops National Park, Jervis Bay, Royal National Park and Sydney Harbour National Park. Dieback of native vegetation has been recognised around Sydney Harbour since the 1950s and in the Royal National Park since the 1970s. Within the SMCMA area, *P. cinnamomi* is thought to be widespread and having a significant and deleterious impact on native ecosystems.

1.2.3 Threat Status

The delicate ecological balance of natural ecosystems is disrupted when *P. cinnamomi* kills susceptible plant species, altering species composition and floristic structure with subsequent losses of food and habitat for native fauna. Infection of native plants by *P. cinnamomi* has been listed as a key threatening process on Schedule 3 of the NSW *Threatened Species Conservation Act* 1995 and under the Australian Government's *Environmental Protection and Biodiversity Conservation Act* 1999.

1.3 *Phytophthora cinnamomi* in the SMCMA area

The SMCMA area extends south from Mona Vale to Stanwell Park, and east from Blacktown to the coast. A recent survey for the presence of *P. cinnamomi* within the SMCMA area (Suddaby, 2008) found that *P. cinnamomi* is present along many walking and vehicle tracks within the National Parks and council reserves, as illustrated in **Figure 1**.

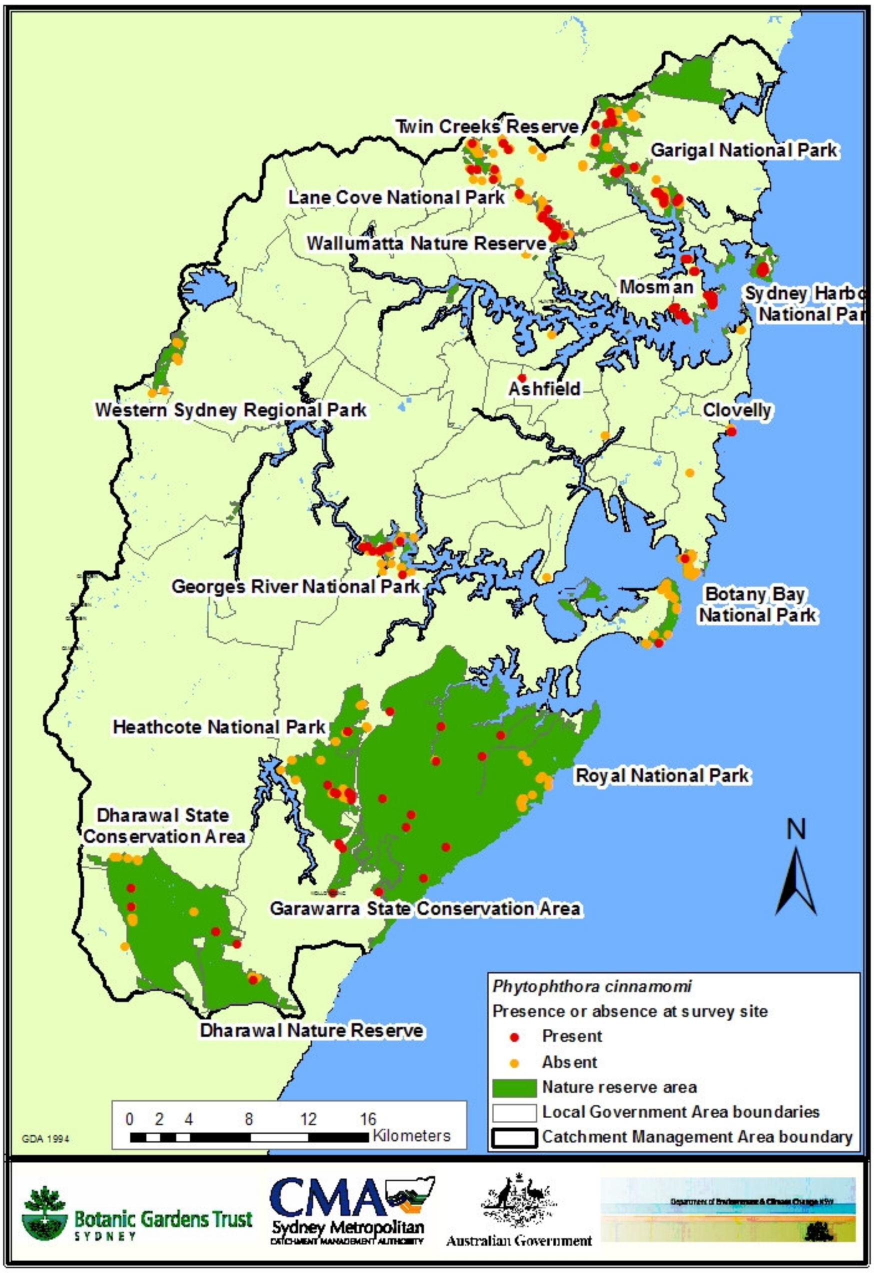

Figure 1 Distribution of *P. cinnamomi* in the Sydney Metropolitan Catchment Management Authority (SMCMA) area

Approximately 69,400 hectares, or 37%, of the SMCMA area is covered by native vegetation, with landscapes varying from rainforest, open woodland heathland and wetlands. Much of this remnant vegetation is conserved within National Parks and local council managed bushland reserves, which are highly valued for their recreational value and conservation significance.

Human activities and the construction of roads and tracks have contributed to the widespread dispersal of the *P. cinnamomi* within the greater Sydney region. Bushland occurring on urban fringes is frequently characterised by a myriad of walking tracks, fire trails and substation access tracks, which support a wide range of activities including bushwalking, cycling, horse and bike riding. These activities allow for the introduction and dispersal of *P. cinnamomi*.

It is likely that *P. cinnamomi* was introduced to infested bushland of the SMCMA area many years ago, however it continues to spread to new hosts or new sites to this day. As such, symptoms of dieback range from acute infection of recently infected plant hosts to long term regeneration of plant species at infested sites. Successful management therefore requires an understanding of the nature of the disease at the local level. Much of the understanding of a particular site depends on records of pathogen detection at specific sites. On-going sampling and documentation of sampling results is crucial. In addition, as part of the sampling and record keeping activity, information on vegetation type and disease symptoms should also be included. This contributes to the understanding of the possible vegetation change due to *Phytophthora* infection.

SECTION 2:
BEST PRACTICE MANAGEMENT GUIDELINES

As an introduced pathogen, it must be assumed that *P. cinnamomi* is not present in bushland unless there is evidence to the contrary. These uninfested bushland sites need to be protected, as there are no known methods to eradicate or prevent the autonomous spread of *P. cinnamomi* from sites once they have become infested. Disease mitigation options in bushland include hygiene protocols, the application of phosphonate, restriction of access to uninfested areas, the provision of educational resources, effective communication between land managers and land users and ex-situ conservation. These topics, excluding ex-situ conservation, will be discussed further in this document.

The extent of the impact that *P. cinnamomi* has in NSW native ecosystems is unknown, due in part to the limited research regarding the susceptibility of individual plant species. In view of this, the RBG Sydney conducted susceptibility trials on 28 NSW species under greenhouse conditions to indicate of how these species would respond to infection in the field. Other than two highly susceptible species (*Pultenaea aristata* and *Eucalyptus sideroxylon*) and two likely to be susceptible (*Grevillea floribunda* and *Isopogon petiolaris*), the majority of species were not found to be highly susceptible under these experimental conditions. Susceptibility to disease varies widely between native plants species and the local environment influences the expression of disease. For this reason management systems need to be adaptive to new knowledge obtained through experience, monitoring and research.

The management of *P. cinnamomi* entails a multitude of specific strategies as outlined in these guidelines. Some involve intensive use of resources (e.g. funds, personnel, expertise) which can be prohibitive when managing a large area. Hence the direction of resources to different sites within an area must be prioritised. For instance, sites exhibiting acute dieback of multiple plants following a recent introduction of the pathogen may require immediate action at the site to limit the extent of the disease front, to conserve susceptible plant species and to prevent erosion on the site from the loss of ground cover species. Actions may include the application of phosphonate and the restriction of access. Alternatively, in areas thought to have harboured the pathogen for a long time or areas within which the pathogen is known to be widely distributed, resources may need to be focused towards the protection of nearby bushland with special reference to highly susceptible plant communities, threatened species and ecological communities. This may be achieved by monitoring for symptoms, the application of phosphonate and the redirection or upgrades of tracks, to contain the disease and to facilitate rehabilitation.

These Best Practice Management guidelines have two major objectives:

1. To minimise the spread of *P. cinnamomi* by human activities into uninfested sites, and
2. To mitigate the impact of *P. cinnamomi* in remnant bushland and high conservation areas.

The following guidelines are structured into four major parts, starting with sampling and detecting *P. cinnamomi*, then disease management strategies based on hygiene protocols, phosphonate application, and lastly, education and awareness raising.

2.1 Surveying for and detection of *P. cinnamomi*

Knowing the distribution of the pathogen and the location of dieback sites is fundamental to effective management of *Phytophthora* dieback. Surveying and mapping must be undertaken before control measures are introduced so that resources are prioritised to where they are needed most and unnecessary measures are avoided. Professional advice should be sought before undertaking a survey for *P. cinnamomi*, however the sampling process is relatively simple and can be undertaken without professional training. The sampling frequency, location and intensity will depend on the purpose of the survey. For example, if the survey is to determine the cause of dieback in a localised stand of bushland, then sampling could be undertaken at the site in question, plus additional sampling at a similar 'control' site which has not exhibited symptoms.

2.1.1 Identifying potentially diseased areas

Areas of potential *P. cinnamomi* infestation can be identified by the presence of dieback symptoms. Individual plants may exhibit symptoms, such as chlorosis (yellowing) of leaves, poor crown development, dieback of major branches, stunted growth and shallow root systems.

Signs of dieback may be visible in plant species that are considered susceptible. Widespread susceptible plants in NSW include *Xanthorrhoea* species (e.g. *X. australis*, *X. glauca* and *X. resinifera*), *Hibbertia* species (e.g. *H. calycina*, *H. virgata*), some heaths (e.g. *Astroloma humifusum*, *Leucopogon ericoides*, *Monotoca elliptica*, *Sprengelia incarnata*, peas (e.g. *Aotus ericoides*, *Bossiaea cinerea*, *Daviesia wyattiana*, *Dillwynia sericea*, *Pultenaea daphnoides*), *Banksia serrata*, *Telopea* species (waratahs), and some *Boronia* and *Tetratheca* species. Such plants can be considered 'indicator plants' for *P. cinnamomi* infection, as they are frequently among the first species to succumb to disease and they succumb relatively quickly or within months (Keith McDougall, pers. comm., 2008). For a further list of susceptibility NSW species, Appendix 4 of the National Best Practice Guidelines should be used as a guide.

Once the first dieback symptoms are detected in one plant, the surveyor should assess the surrounding area to note the general disease pattern, including how the symptoms are distributed across the site, the species and individuals affected, the topography of the site, the severity of symptoms, and other factors such as fires. Disease patterns resulting from infection by *P. cinnamomi* will vary according to the type and number of plant species within an area, environmental factors such as topography and soil health and the length of time the site has been infested. Common distribution patterns of disease include:

- ***Disease fronts*** - Dieback can be visually obvious in recently infested sites containing numerous susceptible species. Vegetation will exhibit an edge effect with a clear boundary between diseased and healthy vegetation, usually occurring along contours and drainage lines.
- ***Introduction points –*** Vehicle, pedestrian and fire tracks, construction sites, earthmoving works, picnic areas, campsites and watercourses crossed by tracks are typical introduction points for the disease into new areas and can be surveyed systematically (see **Section 2.2.2**) in the absence of dieback symptoms.
- ***Age range in plant deaths*** - *P. cinnamomi* spreads autonomously across a site from host to host resulting in an age range in plant deaths. The most recently dead plants will still maintain their leaves.
- ***Tolerant species*** **-** Plants that are infected with *P. cinnamomi* but show minimal symptoms are considered tolerant. These species maintaining levels of inoculum at infested sites and can be a source of new infection.
- ***Dieback phases*** **-** A disease cycle ensues once *P. cinnamomi* is introduced into native bushland. Detecting dieback may depend upon the length of time the pathogen has been present. This is referred to as the age of infection and is particularly relevant in the greater Sydney region, where the pathogen has been known to reside for many years. The phases are classified as follows:
  1. *Early phase*
     - Chlorosis and death of numerous susceptible species of the understorey
     - Dieback of the crown of susceptible trees may occur in 1- 3 years
     - Pathogen population in roots of affected plants is high and sampling is more likely to test positive
  2. *Mid phase*
     - Loss of ground cover and increased surface erosion resulting from the death of susceptible understorey species may occur
     - Regeneration with disease tolerant species, especially sedges and some grasses
     - Regenerated areas are out of character with nearby plant communities
     - Pathogen populations decline which may lead to false negative sampling results
  3. *Late phase*
     - Sites in which *P. cinnamomi* has been present for many years undergo periods of regeneration which may occasionally include some susceptible species

- Overall there is a loss of species richness
- Many samples are needed to detect the pathogen in the soil, as pathogen population is very low

Once dieback symptoms are detected, sampling and diagnosis is the only way to confirm the presence of *P. cinnamomi.* Other possible causes of dieback include nutrient runoff, other plant diseases such as *Armillaria* root rot, soil nutrient toxicity, air pollution, bell minor associated dieback and drought stress. Soil compaction and root damage following construction work can also lead to dieback symptoms, whether or not *P. cinnamomi* is present.

2.1.2 Survey approach

There are two main approaches to surveying for *P. cinnamomi* and both are necessary for effective management of the pathogen.

1. *Systematic surveys* conducted at regular intervals along paths, tracks and watercourses. This is a useful method to determine the distribution of the pathogen and to identify potential sources of infection into bushland. At least two samples per site should be taken. Each sample should consist of four sub-samples obtained from around individual plants, as explained in **Section 2.2.4**.

2. *Targeted surveys* of sites showing signs of dieback, sites containing susceptible species or endangered plant communities, or after high risk events such as fire and flood. This method provides information about the cause and extent of disease, the need to undertake control programs, and the effectiveness of control programs. It will also help to rule out other causes of dieback. Multiple samples per site should be taken plus a sample from at least one control site.

2.1.3 Timing of surveys

Surveys should be conducted when soil temperatures are above 12 degrees Celsius and the sub-soil is very moist. This is because the pathogen is active under these conditions and false negative results are less likely to occur. Late spring and late summer are generally the best times to survey in higher altitude areas, however surveying can be undertaken throughout much of the year in the coastal region around Sydney. Samples should not be taken when the soil surface is saturated as this increases the likelihood of spreading the pathogen harboured in mud on footwear and tools during the surveying process.

2.1.4 Frequency of surveys

Survey results are only representative of conditions at the time they are taken, providing a "snapshot" of conditions. Access points such as tracks or drainage lines (watercourses) leading to sites identified as ecologically important or threatened should be surveyed for the introduction of *P. cinnamomi* at least once every two years or after any high risk event, including after fire, flooding or other disturbances. Surveying may not be necessary on sites identified to be not of particular significance and not subject to any particular form of disturbance (human or natural), unless used as a control site in sampling strategy or prior to any form of construction or anticipated disturbance event.

2.1.5 Survey methodology

The process of surveying is relatively simple; however an initial demonstration by a professional is beneficial. Such demonstration or information may be obtained from the soil testing laboratory (e.g. RBG) or any personnel (e.g. local council, PWS) who has undergone training.

The following equipment is required for sampling:

- Data sheets for recording site information (see example in **Figure 2**)
- A Global Positioning System (GPS) receiver, set to either the Geocentric Datum of Australia (GDA94), Map Grid of Australia (MGA94) or World Geodetic System (WGS84) coordinate systems (see **Section 2.2.7** for further explanation)
- Sterile trowel
- Spray bottle containing 70% methylated spirits or disinfectant
- Sterile sampling bags
- An esky or container (to store samples in)
- Marker pen and pencil
- Backpack or waist belt (to carry equipment)

DATA RECORDING SHEET

Date: ____________________ **Sample number:** ____________________

Name: ____________________ (sampler assigns a number)

1. Site identification (Essential)

Location: ____________________ Aspect: ____________________

Longitude or Eastings (X) ____________________ Altitude: ____________________

Latitude or Southings (Y) ____________________ **Datum, Projection, Zone:** ____________________

2. Site health (Severity of Dieback)

0 healthy (0 plants affected)
1 slight (5-25% plants with symptoms) ________
2 moderate (25-50% plants with symptoms)
3 severe (>50% plants with symptoms)

3. Site Drainage (Optional)

1 poorly drained
2 well drained ________
3 rapidly drained

Soil (Sandy, clay, organic matter)
Leaf litter (cm) ____________________
Soil moisture (dry, moderate, moist, saturated)

4. Plant species

Species	Plant health	Notes
1. The first species is the host plant from which the sample is taken **(Essential)** 2-5. The surrounding plant species (optional)	1 <10% dieback 2 10-50% dieback 3 >50% dieback 4 tree dead, leaves 5 tree dead, no leaves	**Symptoms:** branch death, chlorosis, wilt **Number** of species affected **Other factors:** insect herbivory, fire damage
1		
2		
3		
4		
5		

Other notes:

Fire history

Site disturbance (eg construction site, trackwork, campsite, illegal dumping, flooding)

Site description

Figure 2. An example data recording sheet

To take a sample, the following instructions should be followed:

1. Identify the area(s) you want to sample and select a sampling strategy.
2. To minimise false negative results:
    a. Take at least four (4) samples per site
    b. Where possible, take samples from around live plants exhibiting acute dieback symptoms or from host species known to harbour the pathogen.
3. Scrape away the leaf litter layer and sample the soil underneath, to a depth of approximately 10 cm. The ideal aim is to sample to a depth where there are fine roots and moisture.
    a. When sampling from around small plants, take the sample close to the base of the plant.
    b. When sampling around large trees, take the sample about 1 metre from the base (where the fine roots are).
4. Take four (4) small sub-samples from around the circumference of the symptomatic plant, as shown in **Figure 3**.
    a. Place soil sub-samples into one (1) snap lock plastic bag and seal.
    b. The final sample should total approximately two (2) cups of soil and include the fine roots.
5. Label the bag with collectors name, a sample number and date, ensuring that the number and date correspond with the label on the data sheet.
6. Record the GPS location (easting and southing for GDA94 and MGA94; latitude and longitude for WGS84), datum, projection and map zone on the data sheet.
7. Complete all sections of the data sheet.
8. Between sampling locations, remove excess soil and spray the trowel and footwear and gloves with recommended disinfectant (see **Section 2.3.1**) until runoff is clear.
9. Repeat Steps 3 to 7 as necessary.
10. Transport the samples to a diagnostic laboratory for testing, temporarily storing them at room temperature.
    a. Do not store the samples in a hot car, as the heat will kill *P. cinnamomi*.
    b. Do not refrigerate the samples. Samples can be stored in an esky but not on ice.

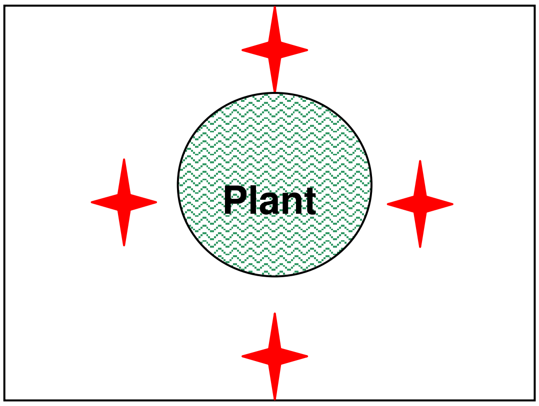

Figure 3 An example of four sub-sample locations around the plant

2.1.6 Soil analysis

The samples are tested in a plant disease diagnostic laboratory for the presence or absence of *P. cinnamomi.* Further information on sampling and diagnostic testing can be obtained from the Royal Botanic Gardens Sydney (www.rbgsyd.nsw.gov.au; (02) 9231 8186).

It should be noted that a negative result from a single sample does not necessary mean that *P. cinnamomi* is absent from this sample site. A false negative result may occur if the pathogen is dormant or as the level of inoculum declines or fragments over time with the disease cycle.

If there is a reason to suspect that *P. cinnamomi* is the cause of dieback but a negative result is obtained, it is advisable to conduct additional surveys.

2.1.7 Maintaining records

Surveying provides far more information than simply the presence or absence of *P. cinnamomi* at a site. Filling in a datasheet (see **Figure 2**) at the point of sampling allows the disease processes such as movement and regeneration to be monitored, identifies environmental factors contributing to dieback, identifies plant hosts which are most susceptible under local environmental conditions, and provides a communication link between ingoing and outgoing management personnel. Site attributes, coordinates and diagnostic results should be entered into an excel spreadsheet, such as in **Figure 4**, for easy access and sharing of information.

Location	Site	Disturbance	Sample_Date	Sample_No	Y_Latitude	X_Longitude	Site_severity	Aspect	Host	*P_cinnamomi*
Miles NP	Track entrance	weeds	12/10/07	MNP1	-33.727972	150.246722	moderate	SE	B. spinulosa	+
Miles NP	Empire track	fire 1 year	12/10/07	MNP2	-33.726778	150.361389	slight	SE	Calicoma	+
Miles NP	Nature trail	track	12/10/07	MNP3	-33.823000	150.365750	severe	SE	B. ericifolia	+
Miles NP	Grass tree walk	track	12/10/07	MNP4	-33.820611	150.397194	slight	SE	Petrophile sp	+
Miles NP	Fern walk	Construction	12/10/07	MNP5	-33.972694	150.389944	slight	NW	B. spinulosa	-
Miles NP	Wild flower walk	track	12/10/07	MNP6	-33.972361	150.313306	healthy	NW	Hakea sp	-
Miles NP	east campsite	campsite	12/10/07	MNP7	-33.986222	150.313306	slight	NW	Acacia sp	+
Miles NP	west campsite	campsite	12/10/07	MNP8	-33.986278	150.313806	slight	NW	Melaleuca sp	+
Miles NP	Industrial ruins	trackwork	12/10/07	MNP9	-33.988167	150.314639	healthy	NW	Indigophora sp	-
Miles NP	CanyonTrack	Fire 2 yr	12/10/07	MNP10	-33.989528	150.313556	slight	W	Eucalypt sp	+
Miles NP	Picnic area	Fire 2 yr	12/10/07	MNP11	-33.992111	150.281667	healthy	W	L.formosa	-
Miles NP	Lookout track	Fire 5 yr	12/10/07	MNP12	-33.172583	150.281278	moderate	W	B.serrata	-

Figure 4. An example spreadsheet containing survey details and results

With the increasing availability of Geographic Information System (GIS) software, a spreadsheet of the survey data can be easily transformed into a table of attributes in a map layer. A map showing the distribution of *P. cinnamomi* can then be layered over other geo-referenced data including topographic and vegetation maps. This form of information will be valuable in determining the distribution, spread and impact of *P. cinnamomi* within an area.

2.1.8 Coordinate systems

To avoid complications when mapping and to maintain database compatibility, samplers should take their coordinates in one datum and ensure that all subsequent coordinates are in the same coordinate system and datum. There are two types of coordinate systems, which differ mainly in the units of measure and information to be documented when recording coordinates:

1. *Projected coordinate systems*: these systems use a mathematical conversion to project the three dimensional shape of the earth onto to two dimensional sheet of paper. Easting and Southing units are in metres which are more for measuring distance and area and ground-truthing with topographic maps. Coordinates should be taken in GDA94/MGA. Datum, projection and the map zone must be recorded.

2. *Geographic coordinate systems*: Latitude (Y-axis) and longitude (X-axis) units are in degrees and are less useful for measuring distance and area. Geographic coordinates should be taken in WGS84 and recorded. WGS84 is useful when surveying and collating map data across different zones.

2.2 Actions to be taken when presence of *P. cinnamomi* is confirmed

- Identify and prioritise sampling to areas of greatest risk of disease, such as those containing threatened species populations and healthy populations of highly susceptible species
- Survey the prioritised area/s and mark the infection boundary
- Identify potential sources of infection, such as bush tracks and drainage lines
- Alert contractors, personnel and volunteers working in the area to the presence of *P cinnamomi* and to the location of at-risk plant communities
- Implement hygiene protocols (see **Section 2.3**)
- Restrict access wherever possible
- Apply phosphonate to protect susceptible species, especially endangered species (see **Section 2.4**)
- Implement track upgrades including track redirection, boardwalks, drainage, and signage (see **Section 2.3.3** and **Section 2.5.1**)

2.3 Hygiene protocols for the management of *P. cinnamomi*

Although thought to be widespread, *P. cinnamomi* is not ubiquitous and the potential to introduce infection into new sites and into new hosts remains significant. Soil or mud on footwear, clothing, vehicles, tyres, equipment and tools, provides the ideal medium to spread *P. cinnamomi.* Hygiene protocols seek to limit the human assisted spread of *P. cinnamomi*. Use of protocols will vary according to the degree of current infestation and/or the risk posed by the introduction of the pathogen into new areas containing threatened or susceptible species and ecological communities.

2.3.1 Recommended disinfectant products and hygiene equipment

Recommended disinfectant products include:

- Non corrosive disinfectants include Coolacide®, Phytoclean® or Biogram® for cleaning footwear, tools, tyres, machinery and other items in contact with soil
- 70% Methylated spirits in spray bottle for personal use
- Sodium Hypochlorite 1% is very effective but can damage clothing and degrades rapidly in light

Recommended hygiene equipment includes:

- Spray bottles
- Measuring cylinder
- Portable wash-down unit
- Large tubs for dipping footwear and tools
- Scraper or course brush to remove mud
- Consider construction of footwear washing stations in 'at risk' ecological areas
- Consider construction of vehicle wash down stations just inside infested areas to protect nearby uninfested 'at risk' ecological areas.

The '*Phytophthora fire response team handbook, Kangaroo Island*' (2003), by the South Australian Department for Environment and Heritage (SA DEH) contains wash-down station assembly, disinfectant mixing rates and procedures. This document is currently available to download from:

http://www.environment.gov.au/biodiversity/invasive/publications/p-cinnamomi/pubs/sa-deh2003a.pdf

2.3.2 Hygiene protocol for working in bushland

- Provide hygiene protocols and induction to all new workers, contractors and volunteers
- Assume the area you are entering in is free of *P. cinnamomi* unless otherwise tested and understand that your activities have the potential to introduce *P. cinnamomi*
- To avoid introducing infection, before entering uninfested sites remove excess soil and mud and then spray boots, tools, gloves and small equipment with recommended disinfectant until runoff is clear
- To avoid spreading *P. cinnamomi*, when leaving infested sites remove excess soil and mud and then spray boots, tools, gloves and small equipment with methylated spirits or disinfectant until runoff is clear
- Plan works so they begin in non- infested sites and then move on to infested areas
- Use coloured tape to label tools when working in infested sites. Remove tape once tools have been cleaned
- Do not work on a site if the soil is saturated and mud is likely to adhere to footwear and tools
- Avoid unnecessary soil disturbance
- Do not import plants unless they are from nurseries accredited with Nursery Industry Accreditation Scheme (NIASA)
- On infested revegetation sites, plant species known to be resistant to *P. cinnamomi*
- Use mulch sourced from disease free native trees and taken from at least one meter above ground level
- Never import soil or gravel unless it is certified to be free of *P. cinnamomi* by plant disease diagnostic laboratory
- All materials removed from a site must be bagged and taken to landfill
- Do not drive or park vehicles or trailers off established tracks
- Use vehicle wash down stations when available
- Ensure effluent from wash down stations does not drain into bushland
- Restrict access in high value areas, particularly if autonomous spread is unlikely to occur

A list of NSW nurseries and Growing Media suppliers accredited under the Nursery Industry Accreditation Scheme Australia (NIASA) is available from the Nursery and Garden Industry Australia (NGIA), phone (02) 9679 1472, email info@ngina.com.au, or website: http://www.ngia.com.au/

2.3.3 Hygiene protocol for track construction

The risks of spreading *P. cinnamomi* during the construction of roads and tracks can be separated into three major categories:

1. Introduction of the pathogen from external location via earthmoving machinery and vehicles carrying infected soil and materials;
2. Existing tracks infested with the pathogen become a source of inoculation to new areas that would have otherwise have remained protected;
3. The area of bushland at risk from autonomous spread of the pathogen is substantially increased when it is adjacent to any track due to the potential for the pathogen to be introduced at new points along the track.

Consequently the first step is to try to minimise the number of tracks through bushland is to consider if a new track is really necessary.

Before commencing construction of a new track:

- Survey for *P. cinnamomi* at all access points, along existing tracks that will cross the proposed new track and the area through which the new track is to be located
- Consider not building new tracks across infested areas or across existing tracks known to be infested
- Ensure *P. cinnamomi* hygiene protocols are included in all construction contracts
- Brief contractors and volunteers undertaking work in *P. cinnamomi* hygiene protocols and ensure that protocols are understood and implemented

During new track design or planning of track maintenance and upgrades, *P. cinnamomi* control measures can easily be implemented with relatively minor modifications:

- Place tracks at a higher elevation than infested areas, so the pathogen does not spread onto the track with water runoff
    - Do not place new tracks on ridge tops above uninfested bushland
- Divert track surface water away from uninfested sites, to the lowest point on the landscape or into natural watercourses
- Incorporate sub-surface drainage (ag-pipe) and drains along the edge of the track
- Where tracks remain pooled with water following rainfall, diverted the track across naturally exposed rock platforms to limit the movement of mud
- Consider upgrading tracks to hard, well drained surfaces
- Where possible, use raised wooden or metal boardwalks to reduce track erosion and disease spread
    - Ecocells can be laid underneath metal boardwalks to capture falling soil

During track construction:

- Clean machinery and footwear before and after entering bushland
    - If a site is heavily infested then machinery may only have to be cleaned before leaving a site, particularly if the machinery is only operated in the local area
- Fence off excavation sites
- Plan works so they begin in non- infested sites and then move on to infested areas
- Do not move or store materials, equipment and machinery outside of the construction zone
- Store excavated material at the construction site or move to waste depots located off-site
- Do not allow track work to take place in wet conditions

The following documents provide comprehensive walking track construction and maintenance with specific reference to *P. cinnamomi* management:

1. The 'Sydney Harbour Federation Trust: Management of *Phytophthora cinnamomi'* (Guest and Daniel, 2004) addresses track construction in urban bushland. This document is currently downloadable from the Sydney Harbour Federation Trust website at: http://www.harbourtrust.gov.au/
2. For risks associated with road and walking tracks, with reference to rainforests, see: Rainforest Dieback: Risks Associated with Roads and Walking Tracks in the Wet Tropics World Heritage Area (Worboys and Gadek, 2004). This document is currently downloadable from the Wet Tropics Management Authority website at: http://www.wettropics.gov.au/

2.3.4 Protocol for fire management

In the case of wildfire, the protection of lives and property has utmost priority. However, fire fighting activities have the potential to spread *P. cinnamomi*. Although the pathogen cannot withstand temperatures above 40 degrees Celsius, it will not be killed at soil depths greater than 20 cm. Current research suggests that fire increases the rate of spread of *P. cinnamomi*, most likely due to the increased runoff water occurring over burnt areas.

- Undertake preliminary surveys for the presence of *P. cinnamomi* at strategic fire fighting points or where firebreaks are likely to be constructed before the fire season begins
- Incorporate hygiene protocols for *P. cinnamomi* (eg Protocol for working in bushland) into existing fire management guidelines.
- Clean fire-fighting machinery and personnel footwear with recommended disinfectant before and after entering bushland
- Minimise soil disturbance by mowing, slashing or using herbicides rather than grading

- Construct firebreaks in uninfested bushland first and then move into infested areas
  - Consider site drainage when constructing firebreaks in infested areas

The '*Phytophthora fire response team handbook, Kangaroo Island'* (SA DEH, 2003) contains guidelines specific to *P. cinnamomi* and fire management. This document is currently available to download from:
http://www.environment.gov.au/biodiversity/invasive/publications/p-cinnamomi/pubs/sa-deh2003a.pdf

2.3.5 Protocol for 4-wheel driving, cycling and horse riding

- Avoid riding or driving in bushland immediately following rain or when the soil is wet
- Avoid riding or driving through muddy tracks and puddles
- Clean soil and mud from hooves, wheels and footwear before entering and after leaving the bushland
- Obey signage which restricts access
- Keep to existing tracks

Protocols for phosphonate application

Phosphonate (also called phosphite) is a biodegradable fungicide that protects plants against *Phytophthora* dieback. It protects the host plants by stressing the *P. cinnamomi* and causing it to release chemical signals. The signals trigger the natural defence mechanisms of the host plant, thereby reducing the ability of *P. cinnamomi* to colonise and reproduce within the host. Consequently while the application of phosphonate will reduce the impact of *P. cinnamomi*, it will not eradicate the pathogen from an infested site.

Phosphonate has very low mammalian toxicity and is quickly biodegraded, therefore its use is considered to be environmentally appropriate for natural ecosystems containing mixed plant communities.

IMPORTANT: The dosage of phosphonate required to protect individual plant species is not universal. Applications that are too high for a particular plant species will have side-effects, such as leaf burning and a reduction in pollen viability, however these effects may be temporary. The recommended phosphonate application concentrations listed below are taken from best management practice guidelines developed by the Western Australian Department of Conservation and Land Management (CALM). These application concentration guidelines are available online at the WA Dieback Working Group (DWG) website: http://www.dwg.org.au/ and should be consulted regularly for updates.

IMPORTANT: It should be noted that phosphonate is not licensed for broad scale use in native vegetation in NSW, however it may be permissible to be used in localised circumstances. The Australian Pesticides and Veterinary Medicine Authority can be contacted for information regarding the allowable application of phosphonate in your area: (Phone (02) 6210 4748; website: http://www.apvma.gov.au/users/subpage_users.shtml).

Recommendations for the application of phosphonate include:

- Apply when plants are actively transpiring, such as during spring and summer.
- To avoid leaf burning, use lower range of recommended concentration by the product manufacturer as indicated on the label when applying to a site for the first time
- Phosphonate can be applied directly to an infested area or as a 30 to 40 metre wide protection zone around a disease front to protect susceptible plants directly in the line of autonomous spread.
- Phosphonate can be injected directly into tree trunks or sprayed onto the foliage of shrubs and herbs. In extreme cases, it can be applied directly as a soil drench.

2.5 Education and raising awareness

2.5.1 Signage

- Install educational signage relating to *Phytophthora* dieback at entry and exit points to susceptible plant communities of cultural and ecological significance, for example, stands of *Xanthorrhoea* species
    - Include a brief introduction to the disease and the disease status of the bushland
    - Request walkers, cyclists and drivers to remain on the track, to avoid using shortcuts through bushland and to use foot wash-down stations upon entry or exit to the area (if available)
- Walking tracks must be easy to follow and well signed to assist walkers in remaining on the track

2.5.2 Raising awareness

Raise awareness of bushland visitors:

- Discuss *Phytophthora* dieback during nature trail tours and eco-events
    - Point out areas or plants showing the symptoms of dieback, to highlight the potential impact on susceptible plant species and biodiversity
    - Talk about how visitors can help to prevent the spread of *P. cinnamomi*
    - Encourage the use of footwear or vehicle wash-down stations at entry and exit points to bushland
- Display brochures pertaining to *P. cinnamomi* at visitor centres and information stands.

Raise awareness of neighbouring landholders:

- Discuss *P. cinnamomi* and the disease status of adjacent bushland with neighbouring landholders
- Promote onsite measures to prevent introducing or spreading the disease:
    - Source landscape materials and plants from NGIA accredited nurseries,
    - Use ‘clean’ disease free mulch from native plant species
    - Redirect drainage water away from bushland
- Promote offsite measures to prevent introducing or spreading the disease:
    - No dumping of green waste or soil into bushland
    - Close informal tracks
    - Phosphonate buffer to protect at risk vegetation
    - Hygiene protocols during construction of firebreaks and control burning.

The brochure '*Facts about Phytophthora'* (Royal Botanic Gardens, Sydney) provides a brief introduction to the disease and management options to people who are unfamiliar with the subject. This brochure (see **Appendix 1**) is available for download from http://www.rbgsyd.nsw.gov.au/__data/assets/pdf_file/90618/Phytophthora_Brochure.pdf

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APPENDIX 1

Brochure: '*Facts about Phytophthora*'

How can I manage Phytophthora?

It is impossible to eradicate *Phytophthora* from infested areas so limiting further spread is critical to management efforts. You can reduce the chances of spreading the disease by:

- Preventing the movement of infected soil or plant material
- Cleaning your shoes when moving in or out of bushland areas
- Making sure your tools are clean before you start working
- Improving organic matter in your garden
- Ensuring your planting material comes from a reputable nursery.

If you think you may have dieback you can have your soil tested for the presence of *Phytophthora*.

What are the Royal Botanic Gardens doing?

In order to effectively manage the disease it is essential to understand where *Phytophthora* occurs. The RBG is surveying the occurrence and distribution of the pathogen. The location of *Phytophthora* will be mapped and information collected will be used to develop and implement management guidelines.

For more information please contact

Plant Disease Diagnostic Unit
Royal Botanic Gardens Sydney
Mrs Macquaries Road
Sydney NSW 2000
Phone: (02) 9231 8138 / 9231 8189
Fax: (02) 9241 1135
Email: pddu@rbgsyd.nsw.gov.au

Plant Disease Diagnostic Unit

Botanic Gardens Trust
SYDNEY

Facts about Phytophthora

Plant Disease Diagnostic Unit

Plant Disease Diagnostic Unit

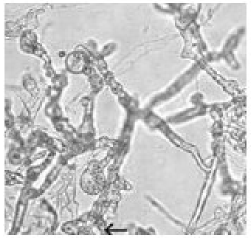
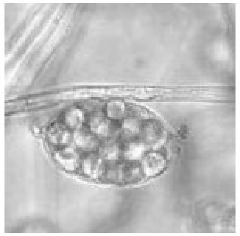
Royal Botanic Gardens, Sydney

Botanic Gardens Trust
SYDNEY

Phytophthora

What is Phytophthora?

Phytophthora (pronounced Fy-toff-thora) is a microscopic organism that lives in soil and plant roots. The name *Phytophthora* is derived from the Greek meaning 'plant-destroyer'. *Phytophthora* causes root rot in a broad range of plant species, including many native Australian and ornamental plants. Around 60 *Phytophthora* species have been identified, but *P. cinnamomi* is the species that is most destructive in native Australian vegetation communities.

Hyphae (left), the vegetative state, and a sporangium with zoospores (right) the main reproductive propagule, of *Phytophthora cinnamomi*.

How does Phytophthora affect plants?

P. cinnamomi attacks the roots and stems of plants, destroying the root system and reducing the ability of the plant to absorb water and nutrients. In susceptible plants, the young roots become dark and rot.

Dieback due to Phytophthora in a heathland community. *Xanthorrhoea* sp. are highly susceptible to *P. cinnamomi*.

Above ground, symptoms include wilting, yellowing and retention of dried foliage. Infection may result in the death of the plant. Symptoms are often more severe, and death more rapid, when plants are suffering from water stress (eg. in summer or drought).


Early symptoms on *Lambertia formosa* (left) compared to a healthy plant (right)

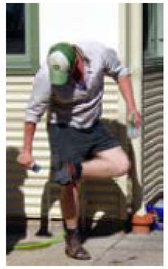
Is Phytophthora a problem in NSW?

The extent of the occurrence of *Phytophthora* in NSW is only beginning to emerge, but the pathogen appears to be more widespread than originally thought. It has been identified in the World Heritage areas of northern NSW, including Barrington Tops NP, the Blue Mountains, including Wollemi NP, in southern NSW near Eden and in bushland reserves around Sydney Harbour.

How is Phytophthora spread?

Phytophthora lives in soil and plant material. Any movement of infested soil or plants can spread the disease. This includes soil on tools, footwear and vehicles.

Phytophthora reproduces very quickly by producing millions of motile zoospores, particularly when the soil is moist and warm. The zoospores can be easily transported in drainage water, especially down slope. When conditions become less favourable, *Phytophthora* produces resistant chlamydospores, which enable it to survive until conditions become conducive again.



Which plants are affected?

Phytophthora cinnamomi threatens the biodiversity of natural ecosystems. The pathogen is known to infect banksias, native peas, eucalypts and ornamentals such as rhododendrons and camellias. It also impacts on native fauna by destroying food sources and habitat.