



**Best Practice Management Guidelines for *Phytophthora cinnamomi*
within the Hawkesbury Nepean Catchment Management Authority
Area.**

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Background for HNCMA

Infection of native plants by *Phytophthora cinnamomi* is listed as a Key Threatening Process under NSW and Commonwealth legislation. The Department of Environment and Climate Change (DECC) has recently produced a Statement of Intent for this pathogen, which outlines the actions required to reduce or eliminate the threat.

In July 2007, the Botanic Gardens Trust Division of DECC commenced the project titled 'Management of the plant pathogen *Phytophthora cinnamomi* within the Hawkesbury Nepean Catchment Management Authority area', funded and initiated by the Hawkesbury Nepean Catchment Management Authority (HNCMA).

The aims of this project were to collate available data and conduct further surveys to determine presence and symptoms of *P. cinnamomi* within the HNCMA area, produce a map showing the location of *P. cinnamomi* in remnant vegetation, test the susceptibility of targeted species and develop educational awareness material to raise awareness of actions to prevent the spread of *P. cinnamomi* with particular reference to habitats at high risk from dieback disease.

Purpose of this Document for HNCMA

This document contains Best Practice Management guidelines developed in response to the survey and the susceptibility trials conducted by the Royal Botanic Gardens, Sydney for the HNCMA. It will assist in the protection of ecological communities that may be at risk as a consequence of dieback disease. It recognises that other Best Practice Management Guidelines are available but has sought to provide information that is most relevant to eastern NSW. These guidelines present a precautionary approach to land management in areas vulnerable to *Phytophthora* dieback. As knowledge about the distribution and impact of *P. cinnamomi* within the HNCMA improves, it will be possible to target hygiene and disease control measures. Until then, adherence to 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.

2. What is Phytophthora dieback?

Phytophthora cinnamomi is a plant pathogen that causes dieback disease in many Australian native plant species. *P. cinnamomi* occurs world wide and affects in excess of 3000 plant species including many Australian native species.

P. cinnamomi is likely to have been introduced into the Sydney region of NSW soon after European settlement. The disease most frequently affects dry sclerophyll vegetation in open forest, woodlands and heathlands in regions experiencing greater than 600 mm annual rainfall and moderate temperatures.

Phytophthora species are not fungi. Unlike fungi, *Phytophthora* species produce 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.

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.

Infection by zoospores occurs during periods of wet soil, usually in Spring or Autumn. Once infected, the small water absorbing roots of woody hosts of native plant species are colonised by the pathogen leading to root rot and death of susceptible plant species. Secondary symptoms come about through the mechanical and physiological damage of a root system. These are the symptoms of a root system in stress and include wilting, chlorosis (yellowing of leaves) and branch death

or 'dieback'. Secondary 'above ground' symptoms may not occur until the damaged root system can no longer compensate for environmental stressors such as drought, commonly occurring in Summer.

Susceptible plant species may die quickly over weeks or branch by branch over many months. Susceptible herbs and shrubs may exhibit wilting of shoot tips, chlorosis of leaves and dieback from shoot tips or of individual branches. Dieback of the crown of susceptible trees begins with browning and then abscission of the leaves, often with epicormic growth. 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 infected.

P. cinnamomi cannot be eradicated from the soil or the roots of infected plants under natural conditions. It generally survives within live root tissues of infected hosts. In addition to the highly infective zoospore, *P. cinnamomi* also produces a hard walled chlamyospore which can survive in the soil or dead root tissues for many months or possibly years.

3. *Phytophthora cinnamomi* in the HNCMA area

The Hawkesbury Nepean catchment contains 2.14 million hectares of land and includes a variety of natural landscapes varying from rainforests, open woodlands heathlands and wetlands. Almost half the catchment is protected within national parks and water catchment reserves. These reserves vary from heavily visited areas on the urban fringes that support a range of outdoor activities including bushwalking, cycling, horse and bike riding and camping in contrast to the vast wilderness of the

greater Blue Mountains region, Yengo, Kanangra and Wollemi NPs which receive less human impact.

P. cinnamomi has been found to be widespread in the highly visited sites in the national parks and reserves of the HNCMA area. It is likely that *P. cinnamomi* was introduced into these areas many years ago, but continues to spread to new hosts or new sites due to autonomous and human assisted dispersal of the spores. As such, symptoms of dieback range from acute infection of recently infected plant hosts to long term regeneration of plant species at infested sites. Therefore successful management requires an understanding of the nature of the disease at the local level.

BEST PRACTICE MANAGEMENT GUIDELINES

Human activities and the construction of roads and tracks have contributed to the widespread dispersal of the *P. cinnamomi* within the greater Sydney region. As an introduced pathogen with the capacity to cause great damage to native vegetation, it must be assumed that *P. cinnamomi* is not present in bushland, unless there is evidence to the contrary and that these sites are in need of protection.

There are no 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 and effective

communication between land managers and land users and ex-situ conservation. These topics, excluding ex-situ conservation, will be discussed 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. 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.

Directing resources must be based on priority. 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. This can include the application of phosphonate and the restriction of access.

Alternatively, in areas thought to have harboured the pathogen for a long time or 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 guidelines have two major objectives:

1. Minimise the spread of *P. cinnamomi* by human activities into uninfested sites

2. Mitigate the impact of *P. cinnamomi* in remnant bushland and high conservation areas

Part 2: Detection

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 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 done 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, a similar 'control' site which was not exhibiting symptoms.

2.1 When to survey

Survey when soil temperatures are above 12°C and the sub-soil is very moist. This is because 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. Do not take samples 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.

2.2 How often to survey

Survey results are only accurate at the time they are taken. Access points such as tracks or drainage lines (watercourses) leading to sites identified as ecologically important or threatened should be surveyed up to once every two years or after any high risk event for the introduction of *P. cinnamomi*. This includes after fire, flooding or other disturbances.

2.3 Where to survey

There are two main approaches to surveying for *P. cinnamomi*. Both approaches are necessary for its effective management.

1) Systematic surveys, 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. Consider taking at least 2 samples per site.

2) Targeted surveys of sites showing signs of dieback, susceptible species, 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, the effectiveness of control programs. It will also help to rule out other causes of dieback. Take multiple samples per site and consider sampling a control site.

2.4 Instructions on how to survey

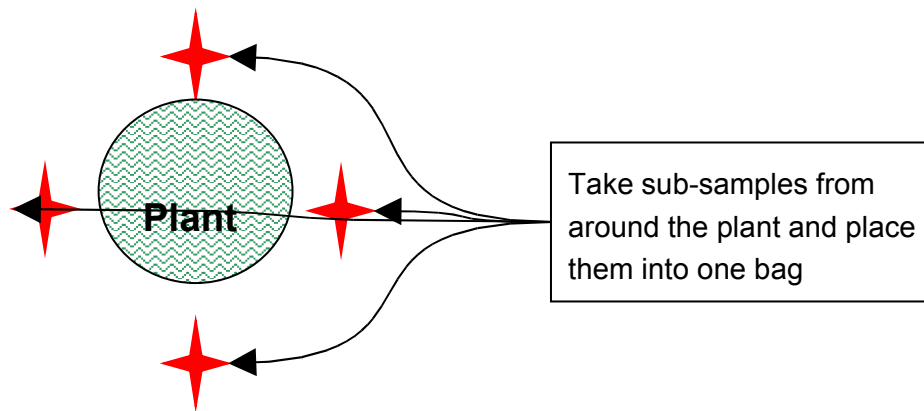
The process of surveying is relatively simple; however an initial demonstration by a professional is beneficial.

Equipment for sampling

1. Data sheets for recording site information
2. GPS need proper name not brand name (set to GDA 94/MGA or WGS 84)
3. Trowel
4. Spray bottle containing 80% methylated spirits or disinfectant
5. Sampling bags
6. Marker pen and pencil
7. Backpack or waist belt

How to take a sample

1. Identify the area(s) you want to sample and a sampling strategy.
2. If possible, select living plants that show symptoms (yellowing, dieback) rather than already dead plants
3. When sampling from around small plants, take the sample close to the base of the plant.
4. When sampling around large trees, take the sample about 1 metre from the base (where the fine roots are).
5. Scrape away the leaf litter layer and sample the soil underneath, to a depth of approximately 10 cm. The aim is to sample to a depth where there are fine roots and soil moisture included in the sample.
6. Take 4 small sub-samples around the circumference of the plant and include the fine roots. The final sample should include up to 2 cups of soil.



7. Place soil into a snap lock plastic bag and seal.
8. 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.
9. Remove excess soil and spray the trowel and footwear and gloves until runoff with methylated spirits or disinfectant between sampling locations.
10. Record the GPS location Latitude Longitude (WGS84) or Easting and Southing (GDA 94 MGA). **Remember to record Datum, Projection and Map zone in the data sheet.**
11. Don't store the samples in a hot car – this will kill *P. cinnamomi*. Store for short term at room temperature
12. Do not refrigerate. Samples can be stored in an esky but not on ice.
13. Return the samples to a diagnostic laboratory for testing.

For information about sampling and diagnostic testing go to:
www.rbg Syd.nsw.gov.au

Unfortunately a negative result from a single sample does not mean that *P. cinnamomi* is absent. Although *P. cinnamomi* cannot be eradicated from an infested site, samples from such sites may return a negative result if the pathogen is dormant or as the level of inoculum declines or fragments over time with the disease/regeneration cycle.

It may be advisable to conduct additional surveys if there is a reason to suspect that *P. cinnamomi* is the cause of dieback and a negative result is obtained. To minimise false negative results take at least 4 samples per site and ensure that samples are taken from around live plants exhibiting acute dieback symptoms or from host species known to harbour the pathogen.

2.5 Maintaining records

Surveying provides far more information than simply the presence or absence of *P. cinnamomi* at a site. Filling in a datasheet at the point of sampling allows the disease process 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. See Fig. 2. Allow some time to enter site attributes, coordinates and diagnostic results into an excel spreadsheet. See Fig.3.

| 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 | | | Soil (Sandy, clay, organic matter) | | | |
| 2 well drained | | | Leaf litter (cm) | | | |
| 3 rapidly drained | | | 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) | 1 <10% dieback | | Symptoms: branch death, chlorosis, wilt | | | |
| | 2 10-50% dieback | | | | | |
| | 3 >50% dieback | | | | | |
| 2-5. The surrounding plant species (optional) | 4 tree dead, leaves | | Number of species affected | | | |
| | 5 tree dead, no leaves | | | | | |
| | | | | | | |
| 1 | | | Other factors: insect herbivory, fire damage | | | |
| 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 sheet for collecting site information

| Location | Site | Disturbance | Sample_Date | Sample_No | Y_Latitude | X_Longitude | Site_severity | Aspect | Host | <i>P_cinnamomi</i> |
|----------|-------------------|--------------|-------------|-----------|------------|-------------|---------------|--------|----------------|--------------------|
| 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 w alk | track | 12/10/07 | MNP4 | -33.820611 | 150.397194 | slight | SE | Petrophile sp | + |
| Miles NP | Fern w alk | Construction | 12/10/07 | MNP5 | -33.972694 | 150.389944 | slight | NW | B. spinulosa | - |
| Miles NP | Wild flower w alk | 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 3. Example of records entered into spreadsheet

Now that Arc-GIS software is readily available, a simple spreadsheet of the survey can become a table of attributes in a map layer. The distribution of *P. cinnamomi* can be layered over other geo-referenced data including topographic and vegetation maps. This information can be valuable in determining of the spread and impact of *P. cinnamomi* within an area.

2.7 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

1. Projected coordinate systems

Use a mathematical conversion to project the 3 dimensional shape of the earth onto to 2 dimensional sheet of paper. Easting and Southing units are in metres which are more useful for measuring distance and area and ground truthing with topographic maps. Coordinates should be taken in GDA94 (Datum), projection (MGA) and the map zone must be specified.

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 taken in the datum WGS84 are useful when surveying and collating map data across different zones. GDA94 projected coordinates are easily obtained from WGS84 coordinates using ArcGIS computer software.

2.8 How to look for dieback

Indicator species - Look for signs of dieback in plant species that are considered susceptible. Widespread susceptible plant sin 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).

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. Infected plants show chlorosis, wilting of shoot tips, dieback of branches and multiple deaths over short periods of time.

Introduction points - Vehicle and pedestrian and fire tracks, construction sites and 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 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 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. This is particularly relevant in the greater Sydney region, where the pathogen has been known to reside for many years.

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 more likely to test positive.

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.

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.

2.9 Websites for susceptible and resistant plant species

For a list of resistant garden plants “Native Garden Plants resistant to Dieback (*Phytophthora cinnamomi*)” by E. Groves, G. Hardy and J.McComb (2003), Murdoch University:

http://www.cpsm.murdoch.edu.au/downloads/resources/B_resistantpecies.pdf

National Best Practice Guidelines/Appendix 4 provides a guide to susceptibility of some NSW species:

<http://www.environment.gov.au/biodiversity/invasive/publications/p-cinnamomi/pubs/appendix4.pdf>

Other causes of dieback

Nutrient runoff, other plant diseases such as *Armillaria* root rot, soil nutrient toxicity, air pollution, bell minor associated dieback, drought stress, soil compaction and root damage following construction work can also lead to dieback symptoms, whether or not *P. cinnamomi* is present.

2.10 Actions to be taken when dieback is found

- Sampling and diagnosis is the only way to confirm the presence of *P. cinnamomi*.
- Identify and prioritise sampling to areas of greatest risk to disease such as threatened species populations and healthy populations of highly susceptible species
- Survey the area and mark the infection boundary
- Identify potential sources of infection, such as bush tracks and drainage lines
- Alert staff; inform contractors and personnel working in the area to the presence of *P. cinnamomi* and to the location of at risk plant communities
- Implement hygiene protocols
- Restrict access wherever possible
- Apply phosphonate to protect susceptible species, especially endangered species
- Track upgrades including, track redirection, boardwalks, drainage, and signage

Part 3: Hygiene Protocols for the management of *Phytophthora cinnamomi*

Although widespread, *P. cinnamomi* is not ubiquitous and the potential to introduce infection into new sites and into new hosts remains significant. 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*.

There are strong reasons for implementing hygiene protocols to manage *P. cinnamomi* despite its widespread occurrence throughout the greater Sydney region. Protocols will vary according to the degree of current infestation, the risk posed by the introduction of the pathogen into new areas containing threatened or susceptible species and ecological communities.

3.1 Working in bushland

- Provide hygiene protocols and induction to all new workers and contractors
- Assume the area you are entering in is free of Phytophthora unless otherwise tested and understand that your activities have the potential to introduce dieback
- To avoid introduction infection, remove excess mud and then spray boots, tools, gloves and small equipment with 70% methylated spirits until runoff before entering uninfested sites
- To avoid spreading *P. cinnamomi*, remove excess mud and then spray boots, tools, gloves and small equipment with methylated spirits or disinfectant *until runoff* when leaving infested sites
- Work in uninfested sites first
- 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 taken from at least one meter above ground level
- Never import soil or gravel unless certified to be free of *P. cinnamomi* a 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
- Effluent from wash down stations should not drain into bushland
- Restrict access in high value areas, particularly if autonomous spread is unlikely to occur

To obtain a list of Nurseries and Growing Media Suppliers accredited under the Nursery Industry Accreditation Scheme Australia (NIASA) or to find out more about this scheme go to: <http://www.ngia.com.au/accreditation/niasa.asp#guidelines>

3.2 Disinfection products

- 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

3.3 Hygiene equipment

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

The 'Phytophthora fire response team handbook, Kangaroo Island by from SA DEH (2003)' contains wash-down station assembly, disinfectant mixing rates and procedures:

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

3.4 Hygiene protocol for track construction

The preplanning stage of track construction, including surveying for the presence or absence of *P. cinnamomi* prior to working is discussed in section 4 of these guidelines.

- Write hygiene protocols into contracts
- Ensure that personnel receive, understand and implement hygiene protocols.
- Machinery and footwear should be cleaned before and after entering bushland
- Fence off excavation sites.
- Work in non- infested sites before travelling to infested areas.

- Do not move or store materials, equipment and machinery in bushland outside of the construction zone.
- Excavated material should be stored at the construction site or taken to waste depots located off-site.
- Do not allow track work to take place in wet conditions
- 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.

3.5 Fire management

Fire fighting activities have the potential to spread *P. cinnamomi*. Although the pathogen cannot withstand temperatures above 40 degrees, it will not be killed at soil depths greater than 20 cm. In the case of wildfire, the protection of lives and property has utmost priority. Hygiene protocols adopted by contractors are also appropriate for prescribed burning and fire break operations.

Preliminary surveys for the presence of *P. cinnamomi* at strategic fire fighting points or where firebreaks are likely to be constructed can be undertaken before the fire season. Hygiene protocols for *P. cinnamomi* can also be incorporated into existing fire management guidelines.

- Machinery and footwear should be cleaned before and after entering bushland
- Soil disturbance can be minimised by mowing, slashing or using herbicides rather than grading
- Construct firebreaks in uninfested bushland first and then move into infested areas.

Current research suggests that fire increases the rate of spread, most likely due to the increased runoff water occurring over burnt out areas. Therefore site drainage may have to be considered when constructing firebreaks in infested areas.

The 'Phytophthora fire response team handbook, Kangaroo Island by from SA DEH (2003)' contains guidelines specific to *P. cinnamomi* and fire management:

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

3.6 Cycling, 4W-driving and horse riding

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

Part 4: Track development

The risk of spreading *P. cinnamomi* associated with the construction of roads and tracks can be separated into 3 major categories:

1. Introduction of the pathogen from external location via earthmoving machinery and vehicles and 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.

4.1 Preconstruction

Before commencing construction:

- 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

4.2 Track design and maintenance

P. cinnamomi control measures can be incorporated into track maintenance and upgrades with relatively minor modifications. Track designs that address erosion such as raised wooden or metal boardwalks can also reduce spreading disease.

- Ecocells can be laid underneath metal boardwalks to capture falling soil

- Place tracks above 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
- Do not construct tracks that pass from infested into uninfested areas
- 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
- Tracks which remain pooled with water following rainfall can to be diverted across naturally exposed rock platforms to limit the movement of mud
- Consider upgrading tracks to hard well drained surfaces
- Minimise the number of tracks through bushland

4.3 Useful Websites for track construction

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

The Sydney Harbour Federation Trust: Management of *Phytophthora cinnamomi* (Guest and Daniel, University of Sydney 2004) addresses track construction in urban bushland:

<http://www.harbourtrust.gov.au/downloads/acrobat/otherpubs/trackreport2004.pdf>

For risks associated with road and walking tracks, with reference to rainforest see: http://www.wettropics.gov.au/res/res_phytophthora.html

Part 5: Phosphonate

Phosphonate also called phosphite is the name given to a number of products which breakdown into the active ingredient, the phosphonate anion (H_2PO_3^-). It protects the plant by stressing the pathogen, causing it to release chemical signals which trigger the natural defence mechanisms of the plant host thus reducing the ability of *P. cinnamomi* to colonise and reproduce within the plant host Phosphonate has very low mammalian toxicity and is rapidly biodegraded. It will not eradicate the pathogen from an infested site. Furthermore, the dosage required to protect individual plant species is not universal. Applications that are too high for a particular plant species will have phytotoxic effects such as leaf burning and a reduction in pollen viability. These effects may be temporary.

5.1 Recommendations for application of phosphonate

- 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
- Use low application rates of phosphonate when applying to a site for the first time to avoid leaf burning
- Apply when plants are actively transpiring such as spring and summer.
- Phosphonate is not licensed for broad scale use in native vegetation in NSW. It may be permissible to use in localised circumstances. Contact the Australian Pesticides and Veterinary Medicine Authority for information regarding the allowable application of phosphonate in your area.

The following link provides comprehensive information regarding the application rates for phosphonate:

<http://www.dwg.org.au/go/about-dieback/phosphite-treatment/index.cfm>

Part 6: Education and communication

6.1 Signage

- Educational signage relating to *Phytophthora* dieback may be useful at entry and exit points to susceptible plant communities of cultural and ecological significance, such as stands of *Xanthorrhoea* species
- Signage specific to *P. cinnamomi* should include a brief introduction to the disease and the disease status of the bushland before requesting walkers, cyclists and drivers to remain on the track, to avoid using shortcuts through bushland or to use foot wash-down stations upon entry or exit to the area.
- Walking tracks must be easy to follow and well signed to assist walkers in remaining on the track

6.2 Raising awareness

Tourism

- Discuss *Phytophthora* dieback during nature trail tours and eco-events, highlighting the potential impact on susceptible plant species and biodiversity along the way and how visitors can help to prevent its spread

- Point out areas or plants showing the symptoms of dieback and use this information to encourage the use of footwear or vehicle wash-down stations at entry and exit points to bushland
- Place brochures pertaining to *P. cinnamomi* at visitor centres and information stands

Landholders

Discuss *P. cinnamomi* and the disease status of adjacent bushland with neighbouring landholders.

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

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.

6.3 On-line educational brochure

The brochure 'Facts about Phytophthora' provides a brief introduction to the disease and management options to people who are unfamiliar with the subject.

It is available online at:

http://www.rbgsyd.nsw.gov.au/__data/assets/pdf_file/90618/Phytophthora_Brochure.pdf

REFERENCES