Monitoring macrofungi on DRF sites sprayed with Phosphite

Progress report – November 2008

Richard Robinson[1], Katrina Syme[2] & Nicole Moore[3]
[1]Department of Environment and Conservation, Science Division, Manjimup, WA.
E-mail: richard.robinson@dec.wa.gov.au
[2]South Coast Hwy, Denmark, WA.
[3]Department of Environment and Conservation, Albany, WA

ACT NOW FOR THE FUTURE

Department of Environment and Conservation
Our environment, our future

Monitoring macrofungi on DRF sites sprayed with Phosphite

Summary

Aerial application of phosphite is critical for the protection of susceptible plant populations in the south coast region of Western Australia. In order to determine if phosphite has any effect on fungal communities, surveys were conducted at Gull Rock and Vancouver Peninsula in July 2004 and June 2007 where populations of *Banksia* have been sprayed at three year intervals since 1996. Sprayed and non-sprayed infested areas had similar fungal assemblages at both Gull Rock and Vancouver Peninsula, The Gull Rock site showed that the diversity of macrofungi is greater in healthy woodland than in woodland infested with *P. cinnamomi*, and that fungal communities in infested woodland (either sprayed or non-sprayed) are vastly different to that found in healthy woodland. It would appear from the findings that dieback has a far greater impact on fungal communities than that of phosphite. We also suggest that a more comprehensive monitoring effort is needed in order to assess whether phosphite has any effect on fungal communities. Additional monitoring also needs to be undertaken to determine the effects that Phytophthora dieback disease has on fungal communities in the south coast region.

Cover Photos: *Main*: Disease front at Gull Rock; *Below from left*: *Banksia coccinea* flower, infested woodland at Vancouver Peninsula, *Psilocybe coprophila, Galerina* sp.

Introduction

Phytophthora cinnamomi, the cause of Phytophthora dieback disease, is a significant threatening process in the south west botanical province (Shearer *et al.* 2007) and is pushing some threatened flora species to the brink of extinction. Currently there is no known method of eradicating the disease once introduced. The use of the chemical phosphite to control *P. cinnamomi* is one of the most important tools available to land managers (McComb *et al.* 2008) in protecting threatened flora. Phosphite is systemically translocated through the plant in both the xylem and the phloem. At higher concentrations it has a direct fungicidal effect on the survival and growth of the pathogen (Smillie *et al.* 1989, Afek and Sztenjnberg 1989) while indirect effects involve those that boost the plants immune response to invasion by the pathogen thus enabling the plant to switch on plant defense mechanisms (Guest 1984, Guest and Grant 1991).

Aerial application of phosphite was developed for use in native plant communities in the early 1990's by the Department of Environment and Conservation (formally the Department of Conservation and Land Management). Ongoing research and monitoring of phosphite treated plant communities continues to show that regular application of phosphite reduces the rate of disease extension, and is effective in increasing plant survival rates and enhancing the health of threatened ecological communities in Western

Australia (Shearer *et al.* 2004, Tynan *et al.* 2001, Moore and Barrett 2007) and in Victoria (Ali and Guest 1998). Ongoing aerial application of low volume phosphite to threatened flora and threatened ecological communities is a critical part of the management actions required by the Department of Environment and Conservation to meet biodiversity protection objectives until effective alternative treatment options are developed.

Fungi comprise a major component of the biodiversity of Australian forest and woodland ecosystems (Bougher 1995, May and Simpson 1997) and they play important roles in the decomposition of organic matter, nutrient recycling and nutrient uptake into plants via mycorrhiza formation (Tommerup and Bougher 2000). These roles are especially important in ecosystems on nutrient poor soils such as those of southwestern Australia (O'Connell and Grove 1996). Fruit bodies of hypogeous (truffle-like) species also form a significant part of the diet of many species of native Australian mammals (Claridge *et al*. 1996) and decay fungi contribute to the development of suitable habitat for many species of native birds and animals (Perry *et al.* 1985, Simpson 1996).

While it is recognised that phosphite application is critical for the protection of susceptible plant populations, it is also important to monitor effects on other components of the biota. In order to determine if phosphite has any effect on fungal communities, surveys were conducted at Gull Rock and Vancouver Peninsula in July 2004 and June 2007 where populations of *Banksia* have been sprayed triennially since 1996. Monitoring is also necessary to satisfy requirements set out by the Australian Pesticides and Veterinary Medicines Authority for the renewal of the off-label permit for the aerial application of phosphite to native vegetation which includes "*Further monitoring of effects on non-pathogenic and beneficial fungi and secondary effects on organisms that depend on these fungi for food and nutrient cycling is required*". Although they are an important component of the fungal flora, hypogeous fungi were not included in the survey, as it would have necessitated major disturbance to the sites that would affect future monitoring.

Monitoring at Gull Rock

Site and treatment

The Gull Rock location occurs in the priority ecological open low *Allocasuarina fraseriana – Eucalyptus staeri* woodland in association with *Banksia coccinea* thicket and is dominated by several species of *Banksia*, including *B. coccinea* and *B. attenuata* infested with *Phytophthora cinnamomi*. The monitoring site, located on Ledge Beach Road, is an infested area approx 1 ha in size, being approx. 0.5 ha on either side of an unnamed track. The area on the western side of the track (Fig. 1) has had two autumn applications (4-6 weeks apart) of phosphite in each of the years 1996, 1999, 2001, 2004 and 2006 at the rate of 40% phosphite at 30 L ha^{-1}. In 2003 a single application of 60% phosphite at 20 L ha^{-1} was applied. The eastern side of the road has not been sprayed (Fig. 1). Each area extends about 120 m north-south and about 30-40 m east-west on either side of the road.

 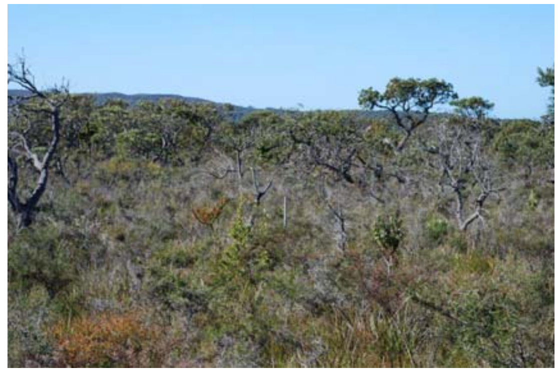

Figure 1. *Banksia coccinea* and *B. attenuata* woodland at Gull Rock infested with *Phytophthora cinnamomi*. *Left*: the disease front on the area sprayed with phosphite and *right*: the disease front in the untreated area.

Healthy woodland dominated by *B. coccinea* (Fig. 2), approximately 200 m north of the infested (and sprayed) area, was used as a 'control' to determine the fungal community on an equivalent but un-infested *B. coccinea-B. attenuata* site.

Figure 2. Healthy *Banksia coccinea* and *B. attenuata* woodland at Gull Rock.

Survey method
In each sprayed and unsprayed area and within the healthy woodland, all macrofungal species and the number of fruit bodies were recorded in each of two 100 m transects. The two transects were 10 m apart, and each was 4 m wide.

Results
Thirty-six species of fungi were recorded at the Gull Rock site, 19 in 2004 and 26 in 2007. In total, 24 species were recorded in the healthy (non-infested) population,12 on the infested area sprayed with phosphite and 14 in the adjacent unsprayed infested area (Table 1). The total number of species recorded on the infested site (combined sprayed and unsprayed area) was 18, of which 8 species were recorded in both the sprayed and

unsprayed area. The macrofungal species assemblages in healthy and infested areas were vastly different. The majority of species recorded in the healthy population were not recorded in the infested population and *vice versa*, as only six species were recorded in both the healthy and infested (combined sprayed and unsprayed)areas. They included an unidentified *Cortinarius* and *Inocybe australiensis* which are mycorrhizal, *Coltricia oblectans* and *Pycnoporus coccineus* which are saprotrophic, a species of *Hypomyces* that was parasitic on *C. oblectans* and the lichenised *Lichenomphalia chromacea*.

Table 1. Species (and abundance) of macrofungi recorded at Gull Rock in healthy and dieback-affected (Pc) woodland in 2004 and 2007.

Species	**Life Mode**[1]	**Healthy**			**Pc + Phosphite**			**Pc - Phosphite**		
		2004	2007	**Total**	2004	2007	**Total**	2004	2007	**Total**
Amanita umbrinella	M	1		**1**						
Calocera sp.	S							42		**42**
Coltricia oblectans	S		5	**5**	9	23	**32**	45	16	**61**
Cortinarius fibrillosus	M		1	**1**						
Cortinarius sp. 'chestnut'	M					4	**4**			
Cortinarius sp. 'purple brown'	M	3		**3**						
Cortinarius sp. 'pointy cap'	M		1	**1**						
Cortinarius sp. (Telamonia)	M		41	**41**						
Cortinarius sp. 'yellow fibrillose cap, white stem'	M		3	**3**						
Cortinarius spp. (unidentified)	M	1	4	**5**	1	1	**2**			
Crepidotus nephrodes	S					2	**2**			
Discinella terrestris	S	35	4	**39**						
Galerina spp.	S								1	**1**
Gymnopilus allantopus	S								3	**3**
Gymnopilus sp. 'slender'	S					11	**11**		5	**5**
Hypomyces sp. on *Coltricia oblectans*	P		1	**1**		2	**2**	2		**2**
*Inocybe*a aff. *australiensis*	M	9		**9**		24	**24**		31	**31**
Inocybe sp. 'scaly cap'	M				11	6	**17**	4	21	**25**
Laccaria lateritia	M				3		**3**			
Laccaria masonii	M				448	610	**1058**	106	3097	**3203**
Lactarius sp. 'creamy yellow'	M		2	**2**						
Lepiota cristata	S	1		**1**						
Lepiota sp. 'creamy brown'	S		1	**1**						
Lichenomphalia chromacea	L	9		**9**		3	**3**	1	2	**3**
Lichenomphalia sp. 'orange'	L		3	**3**						
Marasmiellus sp.	S		53	**53**						
Mycena aff. *maldea*	M		2	**2**						
Mycena mijoi	M	3		**3**						
Mycena sp. 'tiny white, dec. gills, on soil'	S		2	**2**						
Mycena sp. 'orange striate, viscid'	S		3	**3**						
Mycena sp. 'tiny white umbrella'	S	7		**7**						
Omphalotus nidiformis	S							2		**2**

Species	Life Mode[1]	Healthy			Pc + Phosphite			Pc - Phosphite		
		2004	2007	**Total**	2004	2007	**Total**	2004	2007	**Total**
Psilocybe coprophila	S							1		**1**
Pycnoporus coccineus	S	4		**4**					2	**2**
Resupinatus cinerascens	S		8	**8**						
Thelephora aff. *terrestris* 'light brown'	M				2		**2**	6		**6**
# species (Total = 36)		10	16	**24**	6	10	**12**	9	9	**14**
# fruitbodies (Total = 4754)		73	134	**207**	474	686	**1160**	209	3178	**3387**
Number of mycorrhizal species (M)		4	6	**9**	5	5	**7**	3	3	**4**
Number of saprotrophic species (S)		5	8	**12**	1	3	**3**	3	5	**7**
Number of species with other life modes (C/P)		1	2	**3**	0	2	**2**	3	1	**3**

[1] M = mycorrhizal, S = saprotrophic, P = parasitic and L = lichenised (symbiotic with algae)

There was a similar number of species recorded on sprayed and non-sprayed sites within the infested area, but two species, *C. oblectans* (Fig. 3) and *Laccaria masonii* (Fig. 3) were more abundant in the area not sprayed with phosphite (although this varied between the two monitoring years) and *L. masonii*, the most abundant species, was not recorded in the healthy area. Generally, there were even numbers of mycorrhizal and saprotrophic species in each treatment (Table 1).


Figure 3. The most common species found in the infested woodland at Gull Rock. *Left*: *Coltricia oblectans* (note *Hypomyces* sp. on the underside of the middle specimen) and *right*: *Laccaria masonii*.

There was little difference in the species composition between the sprayed and non-sprayed infested areas. The difference in species composition between the infested and healthy areas may be attributed to the lack of groundcover, and the obviously more open nature of the community in the infested area as a result of dieback. The ground cover in the healthy area was dominated by monocots, such as *Lomandra* spp., *Dasypogon bromeliifolius* and *Hypolaena exsulca*, which likely create a moister environment with little or no exposed ground. In contrast, the ground in the infested area was very exposed with little or no litter layer.

Monitoring at Vancouver Peninsula

Site and treatment

The Vancouver Peninsula site is coastal woodland dominated by *Eucalyptus marginata*, *Banksia grandis* and the threatened *B. brownii* (Fig. 3). The sprayed area is approximately 1ha in size (100 x 100m) on a southwest facing slope directly above the shores of Princess Royal Harbour. The site has had two autumn applications (4-6 weeks apart) of phosphite in each of the years 1996, 1999, 2001, 2004 and 2006 at the rate of 40% phosphite at 30 L ha^{-1}. In 2003 a single application of 60% phosphite at 20 L ha^{-1} was applied. An unsprayed area, also 1 ha in size, situated approx. 200 m southeast of the sprayed area was also selected for survey.

Survey method

In each sprayed and unsprayed area all macrofungal species and the number of fruit bodies were recorded on two 100m transects which ran along the contour of the slope. The two transects in each area were about 40 m apart and each was 4 m wide. No monitoring was undertaken on an uninfested area as disease expression at this location was not obvious and it could not be guaranteed that dieback was not present.

Figure 3. *Banksia grandis* - *B. brownii* woodland at Vancouver Peninsula. *Left*: sprayed with phosphite and *right*: untreated.

Results

In all, 61 species of macrofungi were recorded (Table 2), 35 in 2004 and 42 in 2007. Almost twice as many fruit bodies were recorded in 2007. The total number of species recorded in each area was very similar (43 in the area sprayed with phosphite and 39 in the untreated area). There were similar numbers of mycorrhizal and saprotrophic species recorded in each area (Table 2). Twenty one species occurred in both treatments, 22 were only recorded in the area sprayed with phosphite and 18 were only recorded in the unsprayed area, suggesting that species assemblages were different in each area. There were almost three times as many fruit bodies recorded in the area sprayed with phosphite than in the unsprayed area (Table 2).

Table 2: Species (and abundance) of macrofungi recorded at Vancouver Peninsula in 2004 and 2007.

Species	**Life Mode**[1]	**+ Phosphite**			**- Phosphite**		
		2004	2007	**Total**	2004	2007	**Total**
Amanita cf. *bruneibulbosa*	M		1	**1**	1		**1**
Amanita sp. (unidentified)	M	1		**1**	1		**1**
Amanita xanthocephala	M	2	2	**4**			
Armillaria luteobubalina	P/S	8		**8**		5	**5**
Anthracobia sp. 'orange'	M?		100	**100**			
Coltricia oblectans	S	8	2	**10**			
Coprinus spp.	S		3	**3**			
Cortinarius sp. 'brown with purple stem'	M		6	**6**		2	**2**
Cortinarius sp. 'chestnut'	M		2	**2**	9	7	**16**
Cortinarius sp. 'pointy cap'	M		5	**5**		4	**4**
Cortinarius sp. 'purple-brown'	M		30	**30**	5		**5**
Cortinarius sp. (Telamonia)	M					10	**10**
Cortinarius sp. 'viscid orange'	M					1	**1**
Cortinarius sp. 'viscid pink-brown'	M				1		**1**
Cortinarius spp. (unidentified)	M		9	**9**	11		**11**
Discinella terrestris	S					100	**100**
Descolea maculata	M		13	**13**			
Entoloma sp. 'honey'	S	1	1	**2**			
Entoloma sp. 'tall grey-brown, grey stem'	S	2	2	**4**	1		**1**
Fistulinella mollis	S		1	**1**			
Galerina spp.	S	15	43	**58**	11	3	**14**
Grandinia sp. 'simple spines'	S					1	**1**
Gymnopilus allantopus	S					10	**10**
Gymnopilus sp. 'slender'	S				3		**3**
Hydnum repandum	S	44		**44**	2		**2**
Hygrocybe cantharellus	M		2	**2**			
Hygrocybe conica	M	1		**1**			
Inocybe australiensis	M		10	**10**			
Inocybe sp. 'scaly cap'	M	5	1	**6**	4		**4**
Inocybe sp. 'tan skirt'	M	1		**1**			
Laccaria lateritia	M	42	37	**79**	3		**3**
Laccaria masonii	M	59	22	**81**	1		**1**
Lactarius eucalypti	M					2	**2**
Lactarius sp. 'creamy yellow'	M				2		**2**
Marasmius sp. '223'	S					1	**1**

Species	Life Mode[1]	+ Phosphite			- Phosphite		
		2004	2007	**Total**	2004	2007	**Total**
Melanophyllum echinatum	S	2		**2**			
Mycena albidocapillaris	S		25	**25**		1	**1**
Mycena carmelliana	S		2	**2**			
Mycena mijoi	S		1	**1**			
Mycena sanguinolenta	S	1		**1**			
Mycena sp. 'buff umbrella'	S		5	**5**		5	**5**
Mycena sp. 'tiny white scaly cap'	S		6	**6**		1	**1**
Mycena sp. ' tan dome with v. long slender stem'	S	26	14	**40**			
Mycena spp. (unidentified)	S	6		**6**			
Paxillus sp.	M	2		**2**			
Peziza sp. 'hollow sphere'	S				1		**1**
Pisolithus sp.	M	1		**1**			
Pluteus lutescens "yellow'	S					1	**1**
Poronia erici	C					2	**2**
Psathyrella sp.	S	8		**8**	2		**2**
Psilocybe coprophila	C	4	25	**29**	3	4	**7**
Pycnoporus coccineus	S		1	**1**		3	**3**
Ramaria sp. 'grey-brown'	M				9		**9**
Rickenella fibula	S	32	63	**95**			
Russula clelandii	M			**0**		1	**1**
Russula floctonae	M			**0**	1		**1**
Russula neerimea	M	5		**5**	2		**2**
Russula sp. 'white-white-white'	M				4		**4**
Scleroderma cepa	S		1	**1**			
Stereum hirsutum	S				2		**2**
Stropharia semiglobata	C		2	**2**			
# species (Total = 61)		23	31	**43**	22	20	**39**
# fruitbodies (Total = 956)		276	437	**713**	79	164	**243**
Number of mycorrhizal species (M)		13	13	**21**	15	8	**22**
Number of saprotrophic species (S)		10	16	**20**	6	10	**15**
Number of species with other life modes (C/P)		0	2	**2**	1	2	**2**

[1] M = mycorrhizal, S = saprotrophic, P = parasitic, and C = coprophilous

Only two taxa were recorded on both sprayed and non-sprayed areas in both 2004 and 2007. *Galerina* spp. (Fig. 4, a complex of 2-3 very similar and difficult to distinguish species) is saprotrophic and *Psilocybe coprophila* (Fig. 4) which fruits on kangaroo scats. The most common genera recorded were *Cortinarius* (Fig. 4) and *Mycena* with eight species each. Species of *Cortinarius* are mycorrhizal and all eight were recorded in the unsprayed area and five in the sprayed area. *Mycena* are saprotrophic and in contrast to

Cortinarius, all eight were recorded in the sprayed area and only three in the unsprayed area.

Figure 4. Common fungi recorded at Vancouver Peninsula. *Left*: *Galerina* sp.; *centre*: *Psilocybe coprophila*, and *right*; *Cortinarius* sp. 'purple brown'.

Discussion

The Gull Rock site shows that the diversity of macrofungi is greater in healthy woodland than in woodland infested with *P. cinnamomi*, and that fungal communities differ in infested woodland compared to healthy woodland. In jarrah forest, dieback-free and infested sites were found to have significantly different macrofungal floras. Diversity was about 1.8 times greater and abundance 1.5 times greater on dieback-free sites and only 20 % of species occurred on both sites (Anderson 2007). Despite a paucity of species in infested woodland at Gull Rock, the abundance of *L. masonii* was exceptionally high. High abundance of a small number of species is common following disturbance, and has also been reported following fire (Robinson *et al*. 2008).

It is difficult to assess whether phosphite has any effect on fungal communities. It would appear from the findings that dieback has a far greater impact on fungal communities than that of phosphite, presumably through indirect impacts such as the loss of mycorrhizal host plants, a decreased litter layer (Anderson 2007), increased daytime soil temperatures and a decrease in soil moisture (Gochenaur 1981). Species richness was similar on sprayed and unsprayed areas. Species abundance was lower on the sprayed area at Gull Rock (same result if *L. masonii* is not taken into account), but was higher on the sprayed area at Vancouver Peninsula. *L. masonii*, the most dominant species, was more abundant in the unsprayed area at Gull Rock and in the sprayed area at Vancouver Peninsula. Species assemblages in the sprayed and unsprayed areas were different at the Vancouver Peninsula site, but similar at the Gull Rock site (but species diversity was very low at Gull Rock). As suggested in an earlier report (Robinson and Smith 2004), in order to assess whether phosphite has any effect on fungal communities a more comprehensive monitoring effort is needed to capture a larger portion of the fungal flora expected on phosphite treated, untreated and healthy non-infested sites. In addition, and perhaps more important, is the need to determine the effect that Phytophthora dieback disease has on fungal communities in the south coast region.

References

Anderson, P. (2007) *Impact of Phytophthora cinnamomi on macrofungal diversity in the northern jarrah forest.* BSc. Thesis. University of Western Australia, Crawley 6009, Western Australia.

Ali, Z. and Guest, D. I. (1998) Potassium phosphonate controls root rot of *Xanthorrhoea australis* and *X. minor* caused by *Phytophthora cinnamomi*. *Australasian Plant Pathology* **27** 40-44.

Bougher, N. L. (1995) Diversity of ectomycorrhizal fungi associated with eucalypts in Australia. In: Brundette M., Dell, B., Malajczuk, N. and Gond Mingquin (eds) *Mycorrhizas in Plantation Forestry in Asia*. ACIAR Proceedings 62, pp. 8-15.

Claridge, A. W., Castellano, M. A. and Trappe, J. M. (1996) Fungi as a food source for mammals in Australia. In: (eds) *Fungi of Australia Volume 1B. Introduction - Fungi in the Environment.* Australian Biological Resources Study, Canberra., pp. 239-267.

Fenn, M. E. and Coffey, M. D. (1989) Quantification of phosphonate and ethyl phosphonate in tobacco and tomato tissues and the significance for the mode of action of two phosphonate fungicides. *Phytopathology* **79** 76-82.

Gochenaur, S. E. (1981) Respose of fungal commuities to disturbance. In: Wicklow D. T. and Carroll, G. C. (eds) *The Fungal Community: its Organisation and Role in the Ecosystem.* Marcel Dekker Inc., New York, pp. 459-479.

Guest, D. I. (1984) Modification of defence responses in tobacco and capsicum following treatment with fosetyl-Al [Aluminium tris (o-ethyl phosphonate]. *Physiological Plant Pathology* **25** 125-134.

Guest, D. I. and Grant, B. R. (1991) The complex mode of action of phosphonates as antifungal agents. *Biological Review* **66** 159-187.

May, T. W. and Simpson, J. A. (1997) Fungal diversity and ecology in eucalypt ecosystems. In: Williams J. E. and Woinarski, J. C. Z. (eds) *Eucalypt Ecology*. Cambridge University Press, Cambridge, UK, pp. 246-277.

McComb, J. A., O'Brien, P., Calver, M., Staskowski, P., Jardine, N., Eshraghi, L., Ellery, J., Gilovitz, J., O'Brien, J., O'Gara, E., Howard, K., Dell, B. and Hardy, G. E. St.J. (2008) Research into natural and induced resistance in Australian native vegetation of *Phytophthora cinnamomi* and innovative methods to contain and/or eradicate within localised incursions in areas of high biodiversity in Australia. Enhancing the efficacy of phosphite with the addition/supplementation of other chemicals such as those known to be involved in resistance. Prepared by the

Centre for Phytophthora Science and Management for the Australian Government Department of the Environment, Water, Heritage and the Arts.

Moore, N. and Barrett, S. (2007) Phosphite program report 2006/2007. Prepared by the Department of Environment and Conservation, Albany, for the South Coast Natural Resource Management Inc.

O'Connell, A. M. and Grove, T. S. (1996) Biomass production, nutrient uptake and nutrient cycling in the jarrah (*Eucalyptus marginata*) and karri (*Eucalyptus diversicolor*) forests of south-western Australia. In: Attiwill P. M. and Adams, M. A. (eds) *Nutrition of Eucalypts*. CSIRO, Collingwood, Victoria, pp. 155-189.

Perry, D. H., Lenz, M. and Watson, J. A. L. (1985) Relationships between fire, fungal rots and termite damage in Australian forest trees. *Australian Forestry* **49**, 46-53.

Robinson, R. M. and Smith, R. H. (2004) Monitoring macrofungi on DRF sites sprayed with Phosphite. Progress report, July 2004. CALM, Science Division, Kensington, WA.

Robinson, R. M., Mellican, A. and Smith, R. H. (2008) Epigeous macrofungal succession in the first five years following fire in karri regrowth forest in Western Australia. *Austral Ecology* **33**: 807-820.

Shearer BL, Crane CE, Cochrane A (2004) Quantification of the susceptibility of the native flora of the South-West Botanical Province, Western Australia, to *Phytophthora cinnamomi*. *Australian Journal of Botany* **52** 435-443.

Shearer BL, Crane CE, Barrett S and Cochrane A (2007) *Phytophthora cinnamomi* invasion, a major threatening process to conservation of floral diversity in the south-west Botanical Province of Western Australia. *Australian Journal of Botany* **55**:225-238.

Simpson, J. A. (1996) Wood decay fungi. In: (eds) *Fungi of Australia*. Australian Biological Resources Study, Canberra, pp. 95-128.

Smillie R, Grant BR and Guest D (1989) The mode of action of phosphite, evidence for both direct and indirect modes for action on three *Phytophthora* spp. in plants. *Phytopathology* **79** 921-926.

Tommerup, I. C. and Bougher, N. L. (2000) The role of ectomycorrhizal fungi in nutrient cycling in temperate Australian woodlands. In: Hobbs R. J. and Yates, C. J. (eds) *Temperate Eucalypt Woodlands in Australia: Biology, Conservation, Management and Restoration.* Surrey Beatty and Sons, Chipping Norton, pp. 190-224.

Tynan KM, Wilkinson CJ, Holmes JM, Dell B, Colquhoun IJ, McComb JA, Hardy GES (2001) The long-term ability of phosphite to control *Phytophthora cinnamomi* in two native plant communities of Western Australia. *Australian Journal of Botany* **49** 761-770.