Draft Code of Practice on Phytosanitary Controls and Harvesting Techniques for Australian Native Plants: Literature Review

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Introduction

The purpose of this literature review is to collate information relating to existing phytosanitary controls and harvesting techniques for native plants taken from the wild for propagation. The emphasis is on work done in Western Australia.

There are a large number of fungal plant pathogens active in native plant communities. Many of these pathogens are indigenous to these communities and do not threaten ecosystem processes or anthropocentric values attributed to those communities. Others, however, are either exotic and/or have deleterious impacts on ecosystem function and the sustainable conservation of plant communities. They may also constitute a serious threat to cultural heritage or resource exploitation values of these communities.

This literature review only addresses those pathogens that are likely to be spread as a result of harvesting from the wild and that are considered to be important in terms of their ability to disrupt ecosystem processes. The emphasis is on minimising the risk of spreading pathogens from infested to uninfested localities as a consequence of collection activities. The review is heavily weighted to work that has been accomplished in Western Australia and addresses three types of pathogens active there, the Phytophthoras, some canker fungi and *Armillaria luteobubalina* Watling & Kile.

Phytophthora

Phytophthora spp. are introduced soil-borne pathogens belonging to the class Oomycota. They are a relatively primitive collection of fungi belonging to a transitional group between entirely aquatic and completely terrestrial fungi. They are dependent on moist conditions for survival, sporulation, dispersal and infection (Shearer 1994).

In spite of the alternating temperature and moisture regime of a Mediterranean climate with it's cool wet winters and hot dry summers, *Phytophthora cinnamomi* has become a major pathogen in the south west of Western Australia. This is primarily due to the augmented movement of infected soil and plant material by human agents and activities. The soils, topography, local hydrology and susceptibility of plant communities has provided niches where *Phytophthora cinnamomi* can survive the adverse conditions (Shearer 1994) and cause damage. *Phytophthora cinnamomi* is also of concern to land managers in Queensland, NSW, Victoria, Tasmania and South Australia.

Eight taxa of *Phytophthora* have been isolated from native plant communities of Western Australia. These are *P. cinnamomi*, *P. citricola*, *P. megasperma* var. *megasperma*, *P. megasperma* var. *sojae*, *P. drechsleri*, *P. nicotianae* var. *nicotianae*, *P. nicotianae* var. *parasitica* and *P. cryptogea* (Shearer et al. 1989b). There are other *Phytophthora* of concern to the nursery industry such as *P. citrophthora* and *P. palmivora* (Nursery Industry Accreditation Scheme, 1994). However, only *P. cinnamomi* and *P. megasperma* have been considered to be sufficiently pathogenic in native plant ecosystems to warrant the most detailed investigation. In particular, *P. cinnamomi* has been studied in a wide range of ecosystems from the tropical rainforest of Queensland, the alpine ecosystems of Tasmania to the jarrah forest and heaths of Western Australia.

Studies in Victoria by Dawson et al. (1985), Kennedy and Weste (1986), Weste (1975, 1981, & 1986), Weste & Law (1973), Weste & Taylor (1971) and Weste et al. (1973) has shown that *Phytophthora cinnamomi* has severe and permanent impacts on the structure and floristics of dry sclerophyll woodlands, heaths and swamps. Podger et al. (1990) described similar impacts for the vegetation of Tasmania. The impacts of *Phytophthora cinnamomi* on the jarrah forest of WA is described in some detail by Shearer and Tippet (1989b). The vegetation complexes of the south coast of WA have been studied by Hart (1983), Brandis et al.(1985) and Wills (1993), and the banksia woodlands of the Swan Coastal Plain by Podger (1972), Shearer and Hill (1989a), Shearer (1990) and Hill (1990).

All of the above studies indicate a loss of biodiversity by loss of structure (susceptible dominants) and loss of floristics (susceptible species). Studies by Wills and Keighery (1994) found the Proteaceae to be the family of plants most threatened by *Phytophthora cinnamomi*. More than 86% of species assessed were found to be susceptible to *Phytophthora cinnamomi*. Almost all the 233 species of Proteaceae listed by CALM as priority conservation taxa in Western Australia are believed to be susceptible to *Phytophthora cinnamomi* and canker fungi (Wills et al. 1994).

Wills (1993) suggests that, based on research in the Stirling Range NP, as many as 2000 of the 9000 native plant species in the south west of Western Australia may be susceptible to *Phytophthora cinnamomi*. It was also reported that the majority of the species from the Proteaceae, Epacridaceae and Papilionaceae are susceptible. Some 92% of the family Proteaceae tested as being susceptible to *Phytophthora cinnamomi* in field studies

In WA, *P. cinnamomi* is a severe threat to the heaths of the south coast, as many of these plants are susceptible to *Phytophthora cinnamomi*. These vegetation communities also contain a high proportion of vertebrate pollinated flowering plants (Keighery 1982). - The loss of these plants may thus have a secondary effect on the diversity of fauna communities (Friend 1992). The loss of flowering plants also impacts on insects and bird species that are dependent on nectar for food.

Phytophthora cinnamomi has a significant effect on bushland remnants. Being isolated from other bushland there is no opportunity for immigration of resistant species - local extinction and weed invasion is the consequence. An increase in the number of weed species from 2% of species present in uninfected areas to greater than 50% in infected sites has been recorded on reserves in Western Australia (Keighery et al. 1994).

A number of recent publications list the taxa under the greatest threat (Conservation and Land Management 1992, Curry 1992, Curry and Kelly 1993, Keighery 1988a, b, 1991, 1992). Eleven taxa are under greatest threat with most or all population infected. Seven of these are considered under threat of extinction in the wild, and the four other taxa are being monitored (Keighery et al. 1994).

Keighery et al. (1994) considers the combined impacts of disease, fragmentation and increasing levels of disturbance will result in a significant loss of biodiversity. This will be reflected in:

- the change of community structure to favour disease resistant species;
- the extinctions of local population of numerous species and the substantial loss of genetic diversity;

- the likely extinction of many rare and geographically restricted species - both pants and animals through lack of pollinators, food plants and shelter;
- severe genetic erosion of widespread susceptible taxa; and
- a loss of scenic diversity.

The ecological balance is shifting toward simpler, weed invaded plant and animal communities.

There are a number of vectors responsible for the widespread distribution of *Phytophthora cinnamomi* (and other Phytophthoras) that are evident today. Any activity that has the potential to carry infected plant material or infested soil from one locality to another has the potential to spread the pathogen. The pattern of infestations is also symptomatic of the passive movement down hill/down stream of inoculum carried by water (surface and soil water). Infestations are often found "dribbling" downhill from roads or "climbing" upslope (by root to root contact) from drainage lines.

Earth moving operations associated with construction and maintenance of linear utilities such as roads and power line easements appear to be the major cause of spread of *P. cinnamomi* (Shearer et al. 1989, CALM 1994). However, small quantities of infested soil carried on light vehicles or on the footwear of pedestrians also constitutes a significant vector of spread (M. Grant pers comm).

The movement of infected plant material is also an effective vector of spread, either by the inadvertent transfer in field activities, or by the transport of infested seedlings or plants from nurseries. Nursery practice in Australia has been developed to minimise the risk of spreading *Phytophthora* via infected nursery stock (Nursery Industry Accreditation Scheme, 1994).

The collection of plant material from the wild constitutes a significant risk of spreading *Phytophthora*. Wildflower picking, seed collecting and collection of propagation material involves moving from site to site. Vehicles, equipment and even footwear used in these activities have the potential to effectively spread inoculum contained in infested soil from site to site.

There are several hygiene practices that have been developed to minimise the risk of transporting *Phytophthora* inoculum (CALM 1994, Underwood et al. 1983, Barker 1994). These can also be applied to activities associated with taking plant material from the wild and can be broadly grouped as:

- Determining the location and distribution of disease on a site before any activity takes place to highlight the potential for inoculum spread during an operation. This requires specialist expertise that is not readily available to the public. Because flora harvesting activities cover vast areas each year the task of specialist interpretation of disease distribution may be beyond the resources of most State governments. There is, however, scope for training of flora pickers so that they recognise at least some of the signs of dieback. Government agencies can also maintain a program of ongoing identification and mapping of *Phytopthora* "fronts", and use this information when assigning picking areas.

- Restricting access into susceptible areas and, areas that are predominantly disease free. In particular, restricting vehicle access to formed roads only and to periods of the year when soil is dry and unlikely to adhere to vehicles. Restrictions on the extent and timing of access to public land are not easily achieved. Specific legislation similar to and perhaps more wide ranging than that contained in Part VII of the Western Australian *Conservation and Land Management Act 1984* is required to empower such restrictions.Many areas of public land are serviced by poorly constructed and ill-maintained tracks. This access presents a risk of disease spread during periods when the track surfaces are moist. The wildflower harvesting industry requires access to flora when in flower. In most instances in Western Australia this is in autumn and spring when the risk of spreading disease is at its greatest. Other public access also focusses on the spring period. Access rationalisation and upgrading is a large financial undertaking for most land managers. In addition, significant resources are required to enforce legislated restrictions.

- Keeping vehicles, machinery and equipment clean of soil and plant material by cleaning down or by working when soils are not wet and likely to adhere.

  Proper maintenance of clean vehicles and equipment requires an investment in specialised equipment and expertise. Working only in dry times of the year necessitates foregoing opportunities to access native plant communities during moister periods of the year. In the case of professional flower pickers, the time of year when harvesting activity is at its peak in Western Australia is the time of year when the risk of spreading *Phytophthora* is also at its greatest. There is therefore a need to enforce strict hygiene requirements for flora pickers operating during the high disease risk period.

- Confining activities to small, discrete self draining catchment areas separated by cleandown points. The aim being to compartmentalise any disease spread to these discrete areas. This requires an investment in detailed planning and can become quite complex if many machinery or site movements are involved. Intensive management and planning is required.

Hygiene practices for taking plant material for propagation have been identified in a nursery industry accreditation scheme developed by the Australian Horticultural Corporation (1994). Although the scheme aims at minimising the risk of pathogens in nursery operations, harvesting plant material from the wild would also benefit from some of the specified tactics which include:

- taking cutting material at a height sufficient to avoid contaminated soil splashed onto the plant (>0.4m);
- surface sterilisation of cutting material;
- regular disinfection of secateurs and other equipment;
- utilising seed collection in preference to cuttings;
- requiring soil or root material taken from the wild to be quarantined for an appropriate period in an appropriate location; and
- only selecting healthy plant material for collection and keeping this material in quarantine for a period before transfer to the nursery.

Once *Phytophthora* infests a site in the wild there are no techniques currently available that are practical for field control of the organism. Hill and Tippett (1989) compared the use of two fungicides, metalaxyl (Ridomil®) and formaldehyde, and the removal of vegetation, as means of controlling *Phytophthora* infestations. None of the treatments was successful. Disinfestation procedures have been developed for nursery operations (Aust. Hort. Corp., 1994) involving pasteurisation with aerated steam, the use of fumigants such as methyl bromide and Basamid® (Dazomet), and solarisation. These treatments are only practical and economic in high value applications. They are neither practical nor economically feasible in wide scale applications.

The treatment of infected plants using phosphorous acid has been successful, particularly in the treatment of high value horticultural crops such as avocados (Piccone et al. 1987). More recently, Komorek et al. (1994) have successfully applied phosphorous acid as the potassium salt (phosphonate) by stem injection and foliar spray to native plant species. Phosphonate has potential to be a practical and effective control agent for broadscale infestations in native plant communities but is yet to be demonstrated to be so..

Armillaria

The most widespread and pathogenic species of *Armillaria* in Australia is the honey fungus, *Armillaria luteobubalina*. This fungus is endemic to Australia but is of concern to land managers, primary producers and gardeners as it has the ability to cause significant, localised mortality in plant communities.

Armillaria luteobubalina is an indigenous species of gilled mushroom producing primary pathogen of the order Agaricales, class Basidiomycota. Infection occurs from aerially dispersed basidiospores or through mycelial transfer at root contacts.

How basidiospores infect woody tissue is poorly understood and is probably an infrequent event (Kile 1983). The pathogen can spread through disease centres by mycelial growth through roots. In *E. wandoo* Blakely the mean rate of disease extension over 8 years was 2.04+/- 1.05 m/yr (Shearer 1994). In mixed Eucalypt forest of western central Victoria, the pathogen can survive in stumps for up to 30 years (Kile 1981).

Armillaria invades the root systems of living plants causing them to rot. Severe infection can cause morbidity or death. *Armillaria* spreads from one host to another by airborne basidiospores, by the growth of rhizomorphs through the soil, root contact or by transport in infected plant material (Pearce, 1989). Spread is considered to be most commonly caused by root contact and movement of infected material including seedlings.

Armillaria luteobubalina has a wide host range and is commonly found in jarrah, karri, tuart and wandoo forests as well as the woodland and shrublands throughout the south west of WA (Shearer, 1988, 1994, Pearce et al. 1986). In coastal dune shrubland communities 112 of the 307 plant species recorded were host to *A. luteobubalina* (Shearer et al. 1994). Susceptible species were mainly from the Proteaceae, Myrtaceae, Epacridaceae, Papilionaceae and Mimosaceae.

Armillaria has also been of concern to foresters in the eucalypt forest of central Victoria and Tasmania where it has caused mortality in mature and regrowth stands of Eucalyptus (Kellas et al. 1987, Wardlaw et al. 1990). It can also impact on horticultural crops and is a pathogen of apples, stone fruit and citrus (Doepel 1984). It is a significant disease of kiwifruit in New Zealand where at least 150 kiwifruit orchards are known to be infested (Ministry of Agriculture and Fisheries 1988).

Control of the fungus has only been attempted where high value agricultural and horticultural values are affected. Control commonly consists of the removal of all infected plants, the ripping of the soil to expose and recover infected root material and leaving the site fallow for a period sufficient to starve any remaining fungus (Doepel 1984, Von Mueller Institute 1986). Soil cleansing in critical sites has extended to soil sieving and fumigation of soil with a fungicide such as methyl bromide (Ministry of Agriculture and Fisheries, 1988).

Fumigation of stumps infested with *Armillaria* using fumigants such as metham-sodium, dazomet and methyl bromide has been demonstrated to considerably reduce *Armillaria* inoculum (Greig 1990). Pearce et al.(1989) investigated the inoculation of karri (*Eucalyptus diversicolour*) stumps with saprotrophic wood decay fungi that limit the colonisation of stumps by *Armillaria*. The three fungi tested, *Coriolus versicolour*, *Stereum hirustum* and *Xylaria hypoxylon* were effective in reducing *Armillaria* colonisation, as was a naturally occurring cord-forming *Hypholoma* sp. These results offer a promise of biological control agents that can ameliorate adverse impacts on valued plant communities.

There are a number of safeguards that could apply to wild plant harvests to minimise the spread of *Armillaria*. Those harvesting any plant material from the wild should minimise the amount of root material that is taken andcuttings should be from the highest practicable extremity of the plant to minimise the risk of contacting active lesions. Material should only be taken from healthy plants. Also, any seedling taken from the wild in areas of known *Armillaria* infection should be held in quarantine until freedom from *Armillaria* can be demonstrated.

Canker fungi

Canker fungi kill the aerial parts of plants, unlike the diseases caused by *Phytophthora* and *Armillaria* which kill plants from the roots up. Investigation of canker fungi in Western Australia by Shearer and others (Shearer 1994, Shearer et al. 1991a) indicate a large number of host species within the Proteaceae and Myrtaceae.

Several species of canker have been found to be pathogenic to native plant species in Western Australia. *Cryptodiaporthe* stem canker is causing high mortality of *Banksia coccinea* throughout its geographic range (Shearer & Fairman 1991a) and severe branch and stem cankering in *Dryandra sessilis* and *Banksia grandis*. *Zythiostroma* sp. causes stem canker of *Banksia baxteri* and *Botryosphaeria ribis* has debilitated stands of *Banksia speciosa*. *Endothia* sp. have also been associated with cankering of some eucalypts (Shearer 1994). An unidentified canker fungi is seriously debilitating stands of *Dryandra formosa*. Species of *Botryosphaeria* and *Diplodina* have caused extensive damage to large stands of vegetation in the south west of WA (Shearer & Fairman 1991a, Wills 1991, Bathgate et al 1994, Khangura et al 1994, Murray et al 1994, Shearer 1994)

Reproduction and spread is achieved by sexually produced ascospores dispersed in wind currents or asexually produced pycnidiospores dispersed in rain splash. Germinating spores can enter hosts through lenticels or wounds from branch stubs, broken branches or insect damage. Invasion of the phloem and sapwood results in stem damage. Lesion extension can be slow, periodic or rapid, depending on the host - pathogen interaction. Degradation of the stem and crown results in morbidity or death.

Four fungi, *Cytospora sp., Botryosphaeria ribis, Diplodina sp., and Zithiostroma sp.* are commonly isolated from cankers on the south coast of WA. *Botryosphaeria. ribis* and *Diplodina* occur most commonly with *Diplodina* appearing to be the most pathogenic (Bathgate et al. 1994).

Of the 17 stem canker pathogens recorded in a survey by Shearer in 1994, *Botryosphaeria sp.* was the most frequent (54% of reports), followed by *Zythiostroma sp.* (14%) and *Cryptodiaporthe sp.* (11%) (Shearer 1994).

Canker fungi became a concern of land managers in Western Australia in 1989 when a canker, later identified as *Cryptodiaporthe melanocraspeda*, was identified as a threat to *Banksia coccinea* stands. It is now found over the entire range of *B. coccinea* occurrence and is having a significant impact on the conservation status of this species. More recently, an unidentified canker has been observed having a serious impact on stands of *D. formosa*. These stands are geographically discrete, have been visited annually by flora pickers and many are exhibiting signs of canker infestation. There are indications that at least some of the sites not visited by flora pickers still remain healthy (R Smith pers. com.), although this needs to be investigated further to see what other differences there are between infected and healthy sites.

Cryptodiaporthe melanocraspeda invades at wound sites or leaf nodes. The small cankers at leaf nodes quickly expand to girdle the branches and eventually kill the plant. It is believed to be an introduced organism as the widespread destruction observed is not likely to be associated with an indigenous pathogen (Bathgate et al 1994).

Frequency of lesion development is greater in wounded tissue than non-wounded stems and infection rate is greatest in spring and summer. Disease may jump the generation gap by infecting seed. Infected seed germinates and may develop into systemically infected seedlings (Bathgate et al 1994).

The effect of this pathogen plus *Phytophthora* infection on stands of *B. coccinea* resulted in the bush picking of *B. coccinea* being banned on Crown land in 1991 as a strategy to reduce the overall pressure on this species. It is considered that pickers increased the number of infection loci by wounding plants in the process of cutting stems.

Bathgate and co-workers believe that fire may be used as a control of this pathogen. Diseased stands have high fuel loads that result in high fire intensity. However, much seed held in the cone of *B. coccinea* is destroyed by high intensity fire. Low intensity fire may not fully consume all infected material leaving an infection foci for regenerating plants. This may exacerbate disease (Bathgate et al. 1994). The length of the interfire period becomes part of a fine management balance along with fire intensity,seedd storage and regeneration.

Hot gases rising above the flames are sufficient to kill most ascospores and conidia. Unburnt patches however act as infection loci for the regenerating stand. The size and uniformity of the burn is thus critical to successful disease management. Bathgate and co-workers recommend a burning prescription designed to achieve as complete as possible combustion of infected material. Fire intensity should be sufficient to at least completely scorch the *B. coccinea* shrub layer. This is an example of a situation where burning regimes must not only consider the epidemiology of the disease but also the life strategies of affected plants eg canopy stored seed and fire sensitivity.

The collection of plant material from the wild can pose a risk of spreading canker pathogens, but this risk is greatest in plant populations where canker is already present. As spores are transported between plants and populations predominantly by air, it is doubtful that flora pickers moving between populations could pose any significant risk of spreading the disease (the number of spores they would transport would be infinitesimal in comparison with those launched into the air by infected plants). Nevertheless it is conceivable that spores adhering to clothing and equipment could allow the pathogen to be transported between stands of host plants. The major concern for pickers is the potential for them to directly spread infection through secateurs, or knives and that the wounds they leave behind form increased opportunities for future infection. Harvested plant material and seed may also conceivably act as vectors for spreading the pathogen.

Conclusion

Phytophthora, *Armillaria* and canker fungi are the main fungal plant pathogens that are of concern to native plant ecosystem function in Western Australia and some other areas of Australia. All could conceivably be aided in their ability to spread by human vectors. These vectors include bushwalkers, tour groups, sightseers, persons obtaining tissue and plants for the nursery industry or home gardens and also flora cutters. The risks of the spread of infection are, however different between the pathogens and as yet not fully understood. It must be emphasised that the full potential impact of the above pathogens on wild flora populations has not yet been realised. There remain large areas of susceptible vegetation that are not yet affected by these plant pathogens.

While there is very little ability for managers to have any impact on the natural spread of these pathogens, and it is an interesting ethical dilemma to decide to what extent we should attempt to do so, there is a need for managers to develop and implement means of reducing, if not eliminating, their unnatural spread. Those managing the harvesting of wild flora need to ensure that they impose harvest prescriptions that minimise the chances of bush harvesting significantly increasing the risk of spread of the diseases discussed above. In some cases prescriptions will involve closing access to particular sites or species. In others it will involve hygiene strategies and disinfection procedures.

It is suggested that hygiene strategies should be based on:

- Inventories of disease occurrence and the management of these occurrences by quarantine and strictures on access. This requires the development of specialist expertise among land managers to enable the determination of disease distribution. It also requires appropriate legislation to be promulgated to allow the enforcement of quarantine and access restrictions..

- Tactics that minimise the risk of transporting infested soil from one location to another. These should include cleaning of vehicles, machinery, equipment and footwear; operating in high disease risk areas only during times when soil is dry to avoid soil adherence to vehicles and footwear; restricting access seasonally and to specified roads; and compartmentalising work into self contained catchments to limit the extent of a hygiene failure.

  These tactics need to be embraced by the large number of people involved in using public land, including those involved in flora harvesting operations. These operations are typified by very low capitalisation and undertaken by people with limited education and understanding of disease/pathogen dynamics. Many of those active in the industry are involved on a seasonal or casual basis. These characteristics of the flora harvesting industry make it difficult, but not impossible, to promulgate effective hygiene practices.

- Tactics that minimise the risk of transporting infected plant material from one site to another. These should include harvesting only from healthy plants, taking cuttings from as high on the plant as possible to avoid inoculum contained in rain splashed soil or fungal lesions emanating from the collar region of the plant, and quarantining any propagation material to ensure its disease free status before moving it into a nursery.

- Tactics that minimise the risk of transporting the inoculum of canker fungi from one site to another. These could include not harvesting seed or plant material from affected stands, disinfecting or changing clothing before moving to another location, disinfecting hands and all equipment used in the harvesting operation before moving to another site.

The cost to the environment of not implementing appropriate hygiene is likely to be a significantly increased rate of the loss of biodiversity and an irreversible loss of Australia's unique natural heritage. It is, however, important to consider that, unless means of treating diseased plants or of preventing plants and habitats becoming infected through natural spread of spores etc. are developed, this loss of biodiversity will still occurr, but over a longer time frame.

Limiting the spread of the above plant pathogens is a function of education and the commitment of significant resources to hygiene. Awareness in the community and among industry groups using or working on natural lands is paramount to success. Education is required before the widespread application of appropriate hygiene to activities likely to spread or encourage these pathogens is even feasible. Concomitant application of resources to hygiene by industry and government will be necessary. Only by a coordinated approach and the active participation of government, industry and the public users of natural lands can the extent and impact of these pathogens be minimised.

Bibliography

Barker PCJ, 1994, *Phytophthora cinnamomi*: The susceptibility of selected Tasmanian rare species .,A report to Forestry Tasmania and the Australian Nature Conservation Agency,

Bathgate J, Shearer BL, Rohl L, 1994, Cryptodiaporthe sp: a new canker pathogen threatening Banksia coccinea. In: Handbook of the Symposium on Plant Diseases in Ecosystems: Threats and Impacts in South Western Australia (eds RT Wills & WA Cowling) Royal Society of Wester Australia and the Ecological Society of Australia, Perth 19.

Brandis A, Hill T.C.P., Keighery G.J., Tippet J.T., 1985, Protection status and vegetation types in the South Coast Region. Department of Conservation and Land Management, Perth. Unpublished report, 58pp

Conservation and Land Management, 1992, A Nature Conservation Strategy for Western Australia: draft for public comment , Department of Conservation and Land Management, Perth

Department of Conservation and Land Management, 1994, Dieback Disease Hygiene Manual, Department of Conservation and Land Management, Como, Western Australia.

Conservation and Natural Resources, 1992, *Armillaria* root rot: a disease of native and introduced trees, Research and Development, Forest Research Section, Gippsland Division., Scientific Publications Section, Kew, Victoria.

Curry S, 1992, Endangered Prickly Honeysuckle. Landscope 8(2):4

Curry S, Kelly A, 1993, Endangered, the swamp starflower, *Calytrix breviseta* spp *breviseta*. Landscope 8(4):27

Dawson P, Weste G, Ashton D H, 1985, Regeneration of vegetation in the Brisbane ranges after fire and infection with *Phytophthora cinnamomi*. Australian Journal of Botany 33:15-26.

Doepel, R.F., 1984, *Armillaria* root rot., Farmnote No. 90/84, Western Australian Department of Agriculture.

Friend G, 1992, Possum in peril. Landscope 7(3):22-27

Greig, B.J.W., 1990, Stump fumigation as a control measure against honey fungus, In, Research for Practical Arboriculture, ed S.J. Hodge, Forestry Commission Bulletin No. 97., Surrey, UK.

Hardy GE St J, O'Brien PA, Shearer BL, 1994, Control options of plant pathogens in native plant communities in south western Australia. Journal of the Royal Society of Western Australia 77:160-177.

Hart R, 1983, Report on dieback due to *Phytophthora cinnamomi* in Two Peoples Bay Nature Reserve. Department of Fisheries and Wildlife, Perth. Unpublished Report.

Hill, T.C.J., Tippett, J.T., 1989, Comparison of three methods for the eradication of *Phytophthora cinnamomi* from deep leached sands, report for the Roadside Conservation Committee.

Hill T C J, 1990, Dieback disease and other *Phytophthora* species in the northern Kwongan. In: Nature Conservation, landscape and recreation values of the Lesueur area. Environmental Protection Authority, Perth. Bulletin 424.

Keighery G J, 1982, Bird pollinated plants in western Australia and their breeding systems. In: Pollination and Evolution (ed J A Armstrong, JM Powell & AJ Richards) Royal Botanic Gardens, Sydney, 77-89.

Keighery GJ, 1988a, Dieback briefing paper: Epacridaceae. Department of Conservation and Land Management, Perth. Unpublished report, 53 pp

Keighery GJ, 1988b, Endangered, Brown's banksia, *Banksia brownii*. Landscope 3(4):54

Keighery GJ, 1991, Endangered, Dieback Prone Plants of the Eastern Stirling Ranges. Landscope 6(4):43

Keighery GJ, 1992, The impact of *Phytophthora* on rare plants. In: Dieback - What is the Future? The Northern Sandplains Dieback Working Party: Seminar Proceedings, Perth 29-36.

Keighery,GJ, Coates, DJ, Gibson, N, 1994, Future ecosystems - ecological balance (ecological impact of disease causing fungi in south-western Australia, Journal of the Royal Society of Western Australia, 77: 181-184.

Kellas, J.D., Kile, G.A., Jarrett, R.G., Morgan, J.T., 1987, The Occurrence and Effects of *Armillaria luteobubalina* following Partial Cutting in mixed Eucalypt Stands in the Wombat Forest, Victoria., Aust For Res, 17, 263-7

Kennedy J, Weste G, 1986, Vegetation changes associated with invasion by *Phytophthora cinnamomi* on monitored sites in the Grampians, Western Victoria. Australian Journal of Botany 34:251-279.

Khangura R, Hardy GE St J, Wills RT, 1994, Fungi associated with canker in western Australian plant communities. In: Handbook of the Symposium on Plant Diseases in Ecosystems: Threats and Impacts in South Western Australia (eds RT Wills & WA Cowling) Royal Society of Wester Australia and the Ecological Society of Australia, Perth, 26.

Kile GA, 1981, *Armillaria* luteobubalina: aprimary cause of decline and death of trees in mixed species eucalypt forest in central Victoria. Australian Forest Research, 11: 63-77.

Kile GA, 1983, Identification of genotypes and the clonal development of *Armillaria luteobubalina* Watling & Kile in eucalypt forests, Australian Journal of Botany, 31: 657-671

Komorek B, Shearer BL, Smith B, Fairman R, 1994, Phosphonate offers a practical method for the control of *Phytophthora cinnamomi* in native plant communities. In: Handbook of the Symposium on Plant Diseases in Ecosystems: Threats and Impacts in South Western Australia (eds RT Wills & WA Cowling) Royal Society of Wester Australia and the Ecological Society of Australia, Perth 28.

Laidlaw WS, Wilson BA, 1994, Small mammal abundance in heathland with dieback disease in south-eastern Australia. In: Handbook of the Symposium on Plant Diseases in Ecosystems: Threats and Impacts in South Western Australia (eds RT Wills & WA Cowling) Royal Society of Wester Australia and the Ecological Society of Australia, Perth 29.

Malajczuk N, 1979, Biological suppression of *Phytophthora cinnamomi* in Eucalypts and avocado in Australia. In: Soil-Borne Plant Pathogens (eds B Schippers & W Gams) Academic Press, London 635-652.

Malajczuk N, Pearce M, 1994, Impact of plant disease on microbial ecology. In: Handbook of the Symposium on Plant Diseases in Ecosystems: Threats and Impacts in South Western Australia (eds RT Wills & WA Cowling) Royal Society of Wester Australia and the Ecological Society of Australia, Perth 10.

Ministry of Agriculture and Fisheries, 1988, Horticultural Produce and Practice, *Armillaria* in Kiwifruit - Control Measures., Ministry of Agriculture and Fisheries, Wellington, New Zealand.

Murray DIL, Wills RT, Hardy GE St J, 1994, Cankers of native plant species from the south-west of Western Australia. In: Handbook of the Symposium on Plant Diseases in Ecosystems: Threats and Impacts in South Western Australia (eds RT Wills & WA Cowling) Royal Society of Wester Australia and the Ecological Society of Australia, Perth 32.

Nursery Industry Accreditation Scheme, Australia (NIASA), 1994, Australia guidelines, Australian Horticultural Corporation, Level 14, 100 William St, East Sydney, NSW 2011.

Pearce, M.H., Malajczuk, Kile, G.A., 1986, The Occurrence and Effects of *Armillaria luteobubalina* in the Karri (Eucalyptus diversicolour F. Muell.)Forests of Western Australia., Aust. for. res., 16, 243-59.

Pearce, M.H., 1989, The ecology of *Armillaria luteobubalina* Watling and Kile in Karri (*Eucalyptus diversicolour* F. Muell) forest of Western Australia., Phd Thesis, University of Western Australia, School of Agriculture.

Piccone, M.F., Whiley, A.W., Pegg, K.G., 1987, Curing root rot in avocados, Australian Horticulture, Vol 1, No.4.

Podger FD, 1972, *Phytophthora cinnamomi*. a cause of lethal disease in indigenous plant communities in Western Australia. Phytopathology 62:972-981.

Podger FD, Palzer C, Wardlaw T, 1990, A guide to the Tasmanian distribution of *Phytophthora cinnamomi* and its affects on native vegetation. Tasforests 2:13-20.

Shearer BL, 1990, Dieback in south-western Australia. Land and Water Resources Newsletter 5:15-26.

Shearer BL, 1994, The major plant pathogens occurring in ecosystems of south-western Australia. Journal of the Royal Society of Western Australia 77:113-122.

Shearer, B.L., Tippett, J.T., 1988, Distribution and Impact of *Armillaria luteobubalina* in the *Eucalyptus marginata* Forest of South-western Australia., Aust. J. Bot., 36, 433-45.

Shearer BL, Hill T, 1989, Disease of Banksia woodlands of the Swan Coastal Plain In: Banksia Woodland Symposium. Journal of the Royal Society Western Australia, 71:113-114.

Shearer BL, Tippett JT, 1989, Jarrah dieback: The dynamics and management of *Phytophthora cinnamomi* in the jarrah (*Eucalyptus marginata*) forest of Western Australia. Department of Conservation and Land Management, Perth. Research Bulletin 3

Shearer BL, Faiman R, 1991a, Aerial canker fungi threaten Banksia coccinea. In: Conservation Biology in Australia and Oceania Programme. Centre for Conservation Biology, University of Queensland, Brisbane, 65.

Shearer BL, Fairman R, 1991b, Control of *Phytophthora* species in native communities with phosphorous acid. In: Conservation Biology in Australia and Oceania Programme. Centre for Conservation Biology, university of Queensland, Brisbane, 72.

Underwood, R.J., Murch, J.H., 1983, Hygienic logging in the northern jarrah forest, Aust For, Vol. 47, No.1 pg 39-44.

Von Mueller Institute, 1986, *Armillaria* dieback: A disease of native and introduced trees, (R. Hateley Ed), Von Mueller Institute, research and development No. 2, State forests and Lands Service, Conservation Forests and Lands, East Melbourne, Victoria.

Wardlaw, T.J., Bashford, R., Taylor, R., Duckett, T.A.P., 1990, Pests and Diseases management Plan for State Forest in Tasmania (T.J. Wardlaw, ed), Forestry Commission of Tasmania.

Weste G, 1975, The distribution of *Phytophthora cinnamomi* within Wilsons Promontory, Victoria. Australian Journal of Botany 23:67-76.

Weste G, 1981, Changes in vegetation of shrubby sclerophyll woodland associated with invasion by *Phytophthora cinnamomi*. Australian Journal of Botany 29:261-276.

Weste G, 1986, Vegetation changes associated with invasion of *Phytophthora cinnamomi* on defined plots in the Brisbane Ranges, Victoria, 1975-1985. Australian Journal of Botany 34:633-648.

Weste GM, Law C, 1973, The invasion of native forest by *Phytophthora cinnamomi*. Threat to the national Park, Wilsons Promontory. Australian Journal of Botany 21:31-51.

Weste GM, Taylor P, 1971, The invasion of native forest by *Phytophthora cinnamomi*. 1. Brisbane Ranges, Victoria. Australian Journal of Botany, 19:281-294

Weste GM, Cooke D, Taylor P, 1973, The invasion of native forest by *Phytophthora cinnamomi*. Regeneration patterns, declining pathogenicity and attempted control, Australian journal of Botany, 21:13-29

Wills RT, 1991, Pathogenic fungi threaten the conservation of ecosystems in south-west Wester Australia. In: Conservation Biology in Australia and Oceania Programme. Centre for Conservation Biology, University of Queensland, Brisbane, 71.

Wills R, 1993, The ecological impact of *Phytophthora cinnamomi* in the Stirling Range National Park, Western Australia. Australian Journal of Ecology 18:145-159.

Wills RT, Kinnear J, 1993, Threats to the biota of the Stirling Range. In: Mountains of Mystery - A Natural History of the Stirling Range (eds C Thomson, GP Hall & GR Friend) Department of Conservation and Land Management, Como, 135-141.

Wills RT, Keighery GJ, 1994, Ecological impact of plant disease on plant communities, Jooumal of the Royal Society of Western Australia, 77: 127-131.

Wills RT, Robinson CJ, 1994, Threats of plant disease to the wildflower industry, tourism and beekeeping. Journal of the Royal Society of Western Australia 77: 159-162.
