INTERIM RECOVERY PLAN NO. 195

MONTANE MALLEE THICKET OF THE STIRLING RANGE INTERIM RECOVERY PLAN (Mallee-heath and mallee-thicket community on mid to upper slopes of Stirling Range mountains and hills)

2004-2009

by
S. Barrett

Photo: S. Barrett

2005
Department of Conservation and Land Management
Albany Work Centre, South Coast Region,
120 Albany Highway, Albany 6331

Government of Western Australia

DEPARTMENT OF Conservation AND LAND MANAGEMENT
Conserving the nature of WA

Natural Heritage Trust
Helping Communities Helping Australia
An Australian Government Initiative

FOREWORD

Interim Recovery Plans (IRPs) are developed within the framework laid down in Department of Conservation and Land Management (CALM) Policy Statements Nos. 44 and 50.

IRPs outline the recovery actions that are required to urgently address those threatening processes most affecting the ongoing survival of threatened taxa or ecological communities, and begin the recovery process.

CALM is committed to ensuring that Critically Endangered, Endangered and where appropriate and feasible, other threatened ecological communities are conserved through the preparation and implementation of Recovery Plans or Interim Recovery Plans and by ensuring that conservation action commences as soon as possible and always within one year of endorsement of that rank by the Minister.

This Interim Recovery Plan will operate from December 2004 to November 2009 but will remain in force until withdrawn or replaced. It is intended that, if the ecological community is still ranked Endangered, this IRP will be reviewed after five years and the need for a full Recovery Plan assessed.

This IRP was given regional approval on 6 September, 2005 and was approved by the Director of Nature Conservation on 2 October 2005. The allocation of staff time and provision of funds identified in this Interim Recovery Plan is dependent on budgetary and other constraints affecting CALM, as well as the need to address other priorities.

Information in this IRP was accurate at December 2004.

ACKNOWLEDGMENTS

The following people provided valuable advice and assistance in the preparation of this Interim Recovery Plan;

Dr Bryan Shearer, Science Division, Department of Conservation and Land Management
Malcolm Grant, Albany Work Centre, Department of Conservation and Land Management
Rosemarie Rees, Species & Communities Branch (SCB), Department of Conservation and Land Management
Greg Freebury, Albany Work Centre, Department of Conservation and Land Management

SUMMARY

Name: Montane mallee thicket of the Stirling Range (mallee heath and mallee thicket community on mid to upper slopes of Stirling Range mountains and hills).

Description: Mallee heath or mallee thicket community above approximately 400 m above sea level in the Stirling Range. The community occurs on sandy clay-loam over sandstone and metamorphosed sandstone on the mid to upper slopes of mountains and hills in the Range, predominantly east of Red Gum Pass.

Key species that characterise this community include *Banksia solandri, Eucalyptus marginata, B. grandis, B. oreophila, Isopogon latifolius, Dryandra foliolata, D. concinna, Andersonia echinocephala, Adenanthos filifolius, Sphenotoma* sp. Stirling and *Gastrolobium rubrum.* Other mallee-eucalypt species present include, *E. doratoxylon, E. megacarpa* and *E. ligulata* subsp. *stirlingica*.

Departmental Region: South Coast

Departmental District: Albany Work Centre

Local Government Authority: Shires of Gnowangerup and Plantagenet

Recovery Team: The recovery team is as for the TEC "Montane heath and thicket of the South West Botanical Province, above approximately 900 m above sea level (Eastern Stirling Range Montane heath and thicket Community)". The team includes Representatives from CALM's Albany Work Centre, Species and Communities Branch, Science Division, and community representatives.

Current status: This community was assessed by the Western Australian Threatened Ecological Communities Scientific Committee on the 15 February 2002 as Endangered.

Habitat requirements: The floral composition and structure of the Montane mallee thicket community is considered to be related to altitude and aspect, geology, soil type and depth. The community only occurs on sandy clay-loam over sandstone and metamorphosed sandstone including quartzite, slate and phyllite on the mid to upper slopes of mountains and hills, mainly east of Red Gum Pass and above 400 m above sea level.

Habitat critical to the survival of the community and important occurrences: The habitat critical for survival for the Montane mallee thicket community comprises the area of occupancy of the community; similar habitat within 200 metres of the community; remnant vegetation that links the community; and additional nearby occurrences of similar habitat that do not currently contain key species but may have done so in the past. Given that the Montane mallee thicket of the Stirling Range is listed as Endangered all known habitat for the community is considered critical and all occurrences are considered important.

Benefits to other species/ecological communities: There are several Priority species typically associated with the Montane mallee thicket of the Stirling Range community including *Banksia solandri* (P4), *Isopogon latifolius* (P3), *Andersonia echinocephala* (P3), *Sphenotoma* sp. Stirling (P3), *Dryandra concinna* (P4) and *Dryandra foliolata* (P4). Seven threatened species and an additional twenty-four priority species have also been recorded for some of the occurrences of the community. All of these species will benefit from the implementation of recovery actions outlined in this recovery plan. Recovery actions implemented for Occurrence 12 of this community may also benefit an occurrence of the Critically Endangered community Montane heath and thicket of the Eastern Stirling Range, which is immediately adjacent to this community and subject to similar threatening processes. The Critically Endangered flora species *Dryandra anatona* occurs immediately adjacent to this community on Mt Success and South-east Ellen Peak and may also benefit from recovery actions. The threatened mygalomorph, the Stirling Range *Moggridgea* has been recorded from Magog, is considered to be fire sensitive and will benefit from recovery actions that reduce fire frequency and the occurrence of intense fires. Other threatened fauna include Quokka (*Setonix brachyurus*) recorded from Mondurup.

International obligations: This plan is fully consistent with the aims and recommendations of the Convention on Biological Diversity, ratified by Australia in June 1993, and will assist in implementing

Australia's responsibilities under that Convention. The Montane mallee thicket of the Stirling Range community is not listed under any international agreement and none of the flora species identified from this community have been listed under CITES, therefore the implementation of other international environmental responsibilities is not affected by this plan.

Affected interests: Parties affected by this plan include CALM's Albany Work Centre and South Coast Region.

Role and interest of indigenous peoples: Aboriginal people have occupied areas in the vicinity of the Stirling Range for thousands of years and the area has been traditionally regarded as highly significant. The Stirling Range and Porongurup National Parks Management Plan includes an objective to "Identify and protect Aboriginal sites within the Parks" and lists a number of strategies relating to Aboriginal History and Cultural Resources in the park. Several archaeological sites have been identified in and around the Stirling Range National Park although to date no known archaeological sites have been identified within the occurrences of the Montane mallee thicket of the Stirling Range community. Input and involvement will be sought from any indigenous groups that have an active interest in the areas covered by the community.

Social and economic impacts: All occurrences of the Montane mallee thicket of the Stirling Range community are found within an area designated as a National Park and none of the occurrences are subject to a mining lease. Therefore there are no known adverse social and economic impacts from the implementation of this plan.

Evaluation of the plan's performance: CALM, in conjunction with the recovery team will evaluate the performance of this IRP. In addition to annual reporting of the recovery team, the plan is to be reviewed within five years of its implementation.

Guide For Decision-Makers: Section 1 provides details of current and possible future threats. Management of the Stirling Range National Park should continue to take potential impacts on the community into consideration.

Existing recovery actions: A Recovery Team has been established for this community.

IRP Objective(s): To maintain the overall health of intact and relatively intact occurrences of the Montane mallee thicket community and to reduce the level of threat to these areas, so that the community does not move into a higher category of threat during the life of this plan.

Criteria for success:
Maintenance of the richness and composition of native species in those occurrences of the community that are intact or relatively intact in terms of structure, species richness and composition.

Reduction in the impact of *Phytophthora cinnamomi* on the community as measured by improved survival of *Phytophthora cinnamomi* susceptible taxa in infected areas or a reduction in the rate of spread of dieback fronts into disease-free areas.

Criteria for failure:
Significant impact of *Phytophthora cinnamomi* in areas that are intact or relatively intact in terms of species composition.

A sustained or increased level of modification of occurrences of the community as measured by declining survival of *Phytophthora cinnamomi* susceptible taxa in infected areas.

Summary of Recovery Actions:

1. Coordinate recovery actions
2. Assess and map the extent and condition of the community including the extent of *Phytophthora cinnamomi* infestation and the presence of other threats
3. Survey for new occurrences of the community
4. Rank occurrences of the community for urgency of recovery actions, identify key actions
5. Control *P. cinnamomi*: • Apply phosphite to key *P. cinnamomi* infested occurrences • Manage access to *P. cinnamomi*-free occurrences
6. Research population dynamics of *P. cinnamomi*, susceptibility and phosphite application techniques
7. Monitor the rate of spread of *P. cinnamomi* in or adjacent to occurrences of the community and the effectiveness of phosphite application
8. Obtain biological and ecological information, in particular information on the fire ecology of the community
9. Establish long term monitoring to quantify the effect of *P. cinnamomi* on species composition and vegetation structure
10. Establish long term monitoring to quantify the effect of climate change on community biodiversity
11. Develop and implement a fire management strategy
12. Preserve germplasm of key species
13. Promote awareness of the community
14. Incorporate strategies required to protect the community into the Park Management Plan when it is reviewed
15. Write full Recovery Plan if required

1. BACKGROUND

1.1 History, defining characteristics of ecological community, and conservation significance

The flora of the Stirling Range is characterised by a high degree of species diversity with numerous rare and geographically restricted species (Keighery 1993; Hopkins *et al*. 1983). The flora includes both old and relatively recently derived species (Hopkins *et al*. 1983). The number of endemics may be attributed to high levels of speciation and the refugial nature of the mountains, which were subject to a sequence of periods of alternating connection and isolation and fluctuating climates. In the case of the genus *Darwinia,* it has been suggested that landscape dissection, combined with climatic and microclimatic factors, provided geographical isolation and thus facilitated taxonomic divergence (Hopkins *et al*. 1983). It is possible also that a few of the restricted species have never been widespread, either due to being recently derived or through being unable to spread as a result of conservative breeding or dispersal systems.

A biological survey of mountains in southern Western Australia identified several threatened plant communities including the Montane thicket and heath of the South West Botanical Province, above approximately 900m a.s.l (Eastern Stirling Range Montane heath and thicket community) (Barrett 1996; Barrett 2000). It also confirmed the extensive impact of *P. cinnamomi* on the mountain flora of the Stirling Range (Wills 1993, Wills and Keighery 1994; Barrett and Gillen 1997). Further survey since then identified the Montane mallee thicket as a distinctive community that is severely threatened by *P. cinnamomi* (Barrett unpublished data). This community forms part of the Stirling Range vegetation system as described by Beard (1979) who mapped the vegetation at a scale of 1:50,000 with jarrah mallee-heath and thicket occupying the slopes and summits of hills and mountains throughout the Range. This community is referenced by Keighery (1993) as one of two major mallee-heath communities present in the Range, and is described 'as dominated by mallee jarrah and found on mountain tops and slopes'. It is referred to by Pignatti *et al*. (1993) as *Eucalyptus marginata* mallee, occurring preferably on mountain slopes and in relatively moist places.

The Montane mallee thicket community occurs on sandy clay-loam on sandstone and metamorphosed sandstone rock including quartzite, slate and phyllite (Muhling and Brakel 1985) on the mid to upper slopes of mountains and hills, mainly east of Red Gum Pass and above 400 m above sea level. The community generally extends further down-slope on the southern aspects of these hills, which may be due to the moister cooler conditions experienced on these southern aspects. In deeper gullies and saddles the community may be replaced by a marri woodland community**.** The community does not occur on the higher summits east of Chester Pass (above 900 m a.s.l), which is occupied by the Montane heath and thicket TEC. The latter is characterised by an absence of mallee eucalypt species and contains several key species endemic to it, which are not found in the Montane mallee thicket community. The Montane mallee thicket community may occur on the mid-slopes of these higher mountains.

A key indicator species in the Montane mallee thicket community is *Banksia solandri*, other key species include *E. marginata* (mainly shrub-mallee form), *B. grandis*, *B. sphaerocarpa, B. oreophila, Isopogon latifolius, Dryandra foliolata, D. concinna, Andersonia echinocephala, Kunzea montana, Adenanthos filifolius, Sphenotoma* sp. *Stirling, Aotus genistoides* and *Gastrolobium rubrum.* The mallee component consists of species such as *E. doratoxylon*, *E. megacarpa* and *E. ligulata* subsp. *stirlingica* as well as mallee jarrah. The density of the mallee component of community varies with only scattered mallee present on some mountain summits and saddles.

Due to extensive infestation of the Stirling Range by *P. cinnamomi* and loss of key susceptible species, it is difficult to determine the full historical extent of the community. There appears to have been a greater impact of *P. cinnamomi* on summit areas and north facing slopes, which may be due to greater levels of insolation and higher soil temperatures on these aspects (G. Freebury personal communication[1]). The former distribution of the community east of Chester Pass from Coyanerup Peak to Ellen Peak is also difficult to determine. While the summit areas of these mountains are occupied by the Montane thicket and heath community, a mallee thicket and heath community occupies the lower ridgelines. This has been extensively

[1] Greg Freebury, Operations Officer – Nature Conservation, CALM Albany Work Centre

infested and modified by *P. cinnamomi*. A small remnant of Montane mallee thicket still occurs on a ridgeline southeast of Ellen Peak.

Species largely endemic to the community include *Gastrolobium luteifolium, Gastrolobium* sp. *Mondurup, G. vestitum, Hypocalymma phillipsii, Lambertia fairallii, Lasiopetalum dielsii, Dryandra foliolata* and *Darwinia hypericifolia*. Seven threatened species occur within the community (*Gastrolobium luteifolium* (CR), *Leucopogon gnaphalioides* (CR), *Banksia brownii* (CR), *Darwinia wittwerorum* (E), *Daviesia obovata* (E), *Lambertia fairallii* (E) and *Sphenotoma drummondii* (E)). Thirty Priority taxa have been recorded from the community (*Acacia imparilis, Daviesia mesophylla*, *Dryandra ferruginea* subsp. *pumilo, Dryandra plumosa* subsp. *denticulata, Spyridium montanum, Lasiopetalum dielsii*, *Platysace* sp. *Stirling, Gastrolobium crenulatum, Gastrolobium vestita*, *Gonocarpus rudis*, *Muiriantha hassellii* and *Spyridium montanum* (P2) *Isopogon latifolius*, *Andersonia echinocephala*, *Adenanthos filifolius*, *Dryandra hirsuta*, *D. seneciifolia*, *Sphenotoma* sp. Stirling, *Hypocalymma phillipsii*, *Hibbertia argentea*, *Hibbertia helianthemoides, Stylidium verticillatum* and *Velleia foliosa* (P3), *Dryandra concinna, Dryandra foliolata, Banksia solandri, Darwinia lejostyla*, *Darwinia macrostegia, Darwinia hypericifolia* and *Eucalytpus ligulata* subsp. *stirlingica* (P4)). Threatened and priority taxa for each occurrence are listed in Appendix 1.

1.2 Extent and location of occurrences

The community extends from Mondurup Peak, the current western limit of its range, to Mt Success where it abuts the Montane heath and thicket Community with a small remnant at the eastern end of the Range on the ridge southeast of Ellen Peak. The community largely occurs at above 400 m above sea level on the slopes and summit areas of these mountains (Fig. 1a,b). Due to extensive infestation of the Stirling Range by *P. cinnamomi* and loss of key susceptible species, it is difficult to determine the full historical extent of the community and the extent of infested occurrences may have been considerably under estimated. Estimates of the area of intact occurrences and infested occurrences are given in Table 1 based on survey by M. Grant 1988 to 1999; S. Barrett 1994-1996 and 1999 to 2004 and G. Freebury 2002-2004 except where stated. An additional occurrence may be present on the summit of Ross Peak west of Red Gum Pass (G. Keighery personal communication[2]) and this requires further survey. Several occurrences have had no recent survey including Little Mondurup and Twin Hills. Additional occurrences that have not been extensively infested by *P. cinnamomi* are considered unlikely to occur. However, areas not surveyed include the hills south of Toolbrunup.

The total area of the community as it is currently known is approximately 1,385 hectares in 20 occurrences of which approximately 348 hectares is considered to be largely free of *P. cinnamomi*.

Table 1. Approximate area of intact and infested occurrences of Montane Mallee Thicket community with survey method and date.

Occurrence Number	**Location**	Estimated area (ha)		Date	**Survey method**
		Intact	Infested		
Occurrence 1	Baby Barnett	7.6	1.7	2004	On-site
Occurrence 2	Mondurup	82.9	0.0	2004	On-site
Occurrence 3	Little Mondurup	57.7	0.0	1980	Herbarium collections (G. Keighery)
Occurrence 4	Barnett Peak	10.6	87.0	2003	On-site
Occurrence 5	Henton Peak	0.0	181.4	1991	On-site
Occurrence 6	Mt Magog /	11.0	56.0	1996	On-site
	Talyuberlup	10.0	56.0	2004	On-site
Occurrence 7	SW Gog	24.9	4.0	2004	On-site
Occurrence 8	Mt Gog	5.1	26.0	2004	On-site
Occurrence 9 & 10	Twin Hills (W & E)	5.5	34.9	1996	On-site (E. Hickman)

[2] Greg Keighery Principle Research Scientist, Science Division, CALM

Occurrence 11	The Abbey	5.0	112.0	2002	On-site
Occurrence 12	Hostellers	8.0	2.0	2004	On-site
Occurrence 13	Toolbrunup	0.0	108.0	1990	On-site
Occurrence 14	Mt Hassell	2.8	75.0	2004	On-site
Occurrence 15	Mt Trio	8.2	126.0	2003	On-site
Occurrence 16	Toll Peak	39.8	0.0	1999	On-site
Occurrence 17	Yungemere	32.7	82.1	2004	On-site
Occurrence 18	Mt Success	5.3	75.9	2004	On-site
Occurrence 19	Wedge Hill	30.8	1.1	2004	On-site
Occurrence 20	SE Ellen Peak	0.0	5.3	2004	On-site

1.3 Biological and ecological characteristics

Key factors affecting community composition and structure are aspect and exposure, temperature, soil type and depth, fire history and the effects of the introduced plant pathogen *Phytophthora cinnamomi.* The latter is discussed in more detail in Section 1.12 under 'threatening processes'. The soil type is sandy clay loam on sandstone and metamorphosed sandstone including quartzite, slate and phyllite.

1.4 Habitat critical to the survival of the community and important occurrences

The habitat critical for the survival of the Montane mallee thicket community comprises the area of occupancy of the community; similar habitat within 200 metres of the community; remnant vegetation that links the community; and additional nearby occurrences of similar habitat that do not currently contain key species but may have done so in the past. Given that the Montane mallee thicket of the Stirling Range is listed as Endangered all known habitat for the community is considered critical habitat and all occurrences are considered important. Recovery action 3.3 "Rank areas of community for urgency of recovery actions and identify key actions" acknowledges that occurrences of the community should be ranked in terms of their condition and conservation values to enable recovery efforts to be focussed on those priority areas.

1.5 Benefits to other species/ecological communities

There are several Priority species typically associated with the Montane mallee thicket of the Stirling Range community including *Banksia solandri* (P4), *Isopogon latifolius* (P3), *Andersonia echinocephala* (P3), *Sphenotoma* sp. Stirling (P3), *Dryandra concinna* (P4) and *Dryandra foliolata* (P4). Seven threatened species and an additional twenty-four priority species (see section 1.1) have also been recorded for some of the occurrences of the community. All of these species will benefit from the implementation of recovery actions outlined in this recovery plan. Recovery actions implemented for Occurrence 12 of this community may also benefit an occurrence (Occurrence 5, Mt Success) of the Critically Endangered community Montane heath and thicket of the Eastern Stirling Range, which is immediately adjacent to this community and subject to similar threatening processes. The Critically Endangered flora species *Dryandra anatona* occurs immediately adjacent to this community on Mt Success and South-east Ellen Peak and may also benefit from recovery actions. The threatened mygalomorph spider, the Stirling Range *Moggridgea* has been recorded from Magog. It is considered to be fire sensitive (Main and Gaull 1993) and will benefit from recovery actions that reduce fire frequency and the occurrence of intense fires. Other threatened fauna include Quokka (*Setonix brachyurus*) recorded from Mondurup.

1.6 International obligations

This plan is fully consistent with the aims and recommendations of the Convention on Biological Diversity, ratified by Australia in June 1993, and will assist in implementing Australia's responsibilities under that Convention. The Montane mallee thicket of the Stirling Range community is not listed under any international agreement and none of the flora species identified from this community have been listed under CITES, therefore the implementation of other international environmental responsibilities is not affected by this plan.

1.7 Affected interests

Parties affected by this plan include CALM's Albany Work Centre and South Coast Region.

1.8 Role and interest of indigenous peoples

Aboriginal people have occupied areas in the vicinity of the Stirling Range for thousands of years and the area has been traditionally regarded as highly significant (Allan & Herford 1999; Leighton 1993). The Stirling Range and Porongurup National Parks Management Plan includes an objective to "Identify and protect Aboriginal sites within the Parks" and lists a number of strategies relating to Aboriginal History and Cultural Resources in the park including "2 Ensure that activities in the park do not impact detrimentally upon known aboriginal sites". Several archaeological sites have been identified in and around the Stirling Range National Park although to date no known archaeological sites have been identified within the occurrences of the Montane mallee thicket of the Stirling Range community. Input and involvement will be sought from any indigenous groups that have an active interest in the areas covered by the community.

1.9 Social and economic impacts

All occurrences of the Montane mallee thicket of the Stirling Range community are found within an area designated as a National Park and none of the occurrences are subject to a mining lease. Therefore there are no known adverse social and economic impacts from the implementation of this plan.

1.10 Evaluation of the plan's performance

CALM, in conjunction with the recovery team will evaluate the performance of this IRP. In addition to annual reporting of the recovery team, the plan is to be reviewed within five years of its implementation.

1.11 Historical and Current Threatening Processes

The Montane mallee thicket community has been subject to historical disturbance by the plant disease resulting from the introduced root-rot pathogen *Phytophthora cinnamomi*.

Of the current threats to the Montane mallee thicket community the most significant is unequivocally *P. cinnamomi* infection (Wills 1993; Barrett 1996; Barrett and Gillen 1997). However, other threatening processes exist (see below), including the impact of frequent, intense and extensive fire and disturbance due to recreational activities, both of which impact on the disease process also. A potentially less significant threat is grazing by rabbits and minor weed infestations.

The community is subject to the following threatening processes (in approximate order of level of threat posed):

- ***Phytophthora cinnamomi***

The Stirling Range has a long history of use and it is difficult to determine when the *P. cinnamomi* may have been introduced. The construction and use of an extensive firebreak system in the 1960s presented an ideal opportunity for the spread of the disease over much of the Park. CSIRO researchers noted that the disease was evident in 1974 (Department of Conservation and Land Management 1997).

The distribution and severity of *P. cinnamomi* infestation in plant communities is influenced by plant species susceptibility, temperature, soil type, nutrient status and water availability (Weste and Marks 1987; Shearer and Tippett 1989; Wilson *et al*. 1994). The impact of this pathogen is especially devastating in the species-rich areas of southern Western Australia. Here, climatic conditions combine with soils, topography and susceptible plant communities to create ideal conditions for the sporulation and survival of the pathogen, and the dispersal of *P. cinnamomi* through root to root contact or in soil water flow and plant infection (Grant and Barrett 2003). However, there has been no study to date of the population dynamics of *P. cinnamomi* in south coast soils including those of the Stirling Range and this cannot be extrapolated from previous studies in the jarrah forest or Swan Coastal Plain (B. Shearer personal communication)

It is apparent that the pathogen has been spread to many of the peaks in the Stirling Range through the transport of infected soil, mainly by foot access. Infections high in the landscape have led to considerable down-slope spread in broad fronts (Department of Conservation and Land Management 1997). Broadscale mapping of *P. cinnamomi* from 1986 to 1995 suggested that over 60% of the Stirling Range National Park was infested by the pathogen and an additional 10% was exposed to future uncontrolled spread of the pathogen (Grant and Barrett 2003). Only one mountain peak, Mondurup, out of 17 with altitudes greater than 750 m elevation above sea level had escaped infestation. Orographic rain (Courtenay 1993) in combination with the presence of a species-rich plant community dominated by susceptible members of the Proteaceae, Papilionaceae, Myrtaceae and Epacridaceae growing on nutrient deficient shallow soils provides ideal conditions for sporulation, survival, dispersal and infection. Once established, the pathogen can spread at greatly increased rates of up to 250 metres per annum down slope from mountain summits. A large number of plant taxa including endemic, threatened and priority taxa that occur in the Montane mallee thicket community are highly susceptible to *P. cinnamomi* infection. These taxa are predominantly members of the families Proteaceae, Epacridaceae and Papilionaceae. Infestation results in death of susceptible species and significant changes in structure and species composition. Many susceptible species are key structural components of the community and important food sources for nectivorous fauna. Changes in resource availability and habitat may affect associated groups of fauna (Wilson *et al*. 1994; Nichols 1998).

Long term (24 years) monitoring of changes in vegetation, pathogen population and distribution data in relation to *P. cinnamomi* infestation has been conducted in the Grampians, Western Victoria (Weste *et al*. 2002). This showed post-infection colonisation of susceptible species on some sites with resistant species dominating at others. There has been no similar study conducted to date in Western Australia and the long term outcome at infested sites is unclear.

Current occurrences of the Montane mallee thicket community that are considered to be largely *Phytophthora*-free are the summit and upper slopes of Mondurup Peak, Wedge Hill, Yungemere, the ridge southwest of Gog, Toll Peak, Baby Barnett, Hosteller Hills and Little Mondurup. However, Yungemere, Mondurup, Southwest Gog, Baby Barnett, Hostellers Hills and Wedge Hill have extensive infestations downslope. Yungemere also has scattered spot infestations on its southern and southeastern ridges and gullies as well as the northeastern end of the summit ridge. There are small infections on four of the southerly ridge systems off the main ridge southwest of Gog as well as the eastern end of this ridge. A small infestation also exists between the 500 and 550 metre contour on the main ridge east of Wedge Hill. There are small spot infestations mid-slope in the Hostellers Hills occurrence. There is an incremental autonomous spread of *Phytophthora* to non-infested habitat in these occurrences annually.

The remaining occurrences (the Abbey, Barnett Peak, Baby Barnett, Henton Peak, Twin Hills, Magog, Gog, Talyuberlup, Mt Hassell, Mt Trio, Toolbrunup, South-east Ellen Peak and Mt Success) have extensive infestations with small remnants of intact vegetation. Further assessment of the distribution and health of occurrences of this community is required using aerial photography combined with ground truthing.

Phosphite application

Research has shown that application of the fungicide phosphite by stem injection, soil drench or foliar spray is effective in controlling *Phytophthora cinnamomi* in a range of native species (Shearer and Fairman 1991, 1997; Komorek *et al*. 1997; Ali and Guest 1998; Aberton *et al*. 1999; Wilkinson *et al*. 2001). Aerial phosphite application techniques enable the spraying of whole plant communities as well as individual species (Komorek *et al*. 1997; Barrett 2003). Phosphite may be applied to healthy vegetation adjacent to dieback fronts to slow the spread of the pathogen or to infested vegetation in order to slow the decline of susceptible species persisting within infestations. Although phosphite has proven to be effective in localised control of the disease, lack of knowledge of the population dynamics of the disease in south coast soils, rates of spread and disease susceptibility significantly hampers effective management of this disease (B. Shearer personal communication[3]).

[3] Bryan Shearer, Principal Research Scientist, CALM

Aerial phosphite application is currently the only feasible application technique for remote upland plant communities. Phosphite spraying commenced in the Stirling Range National Park in 1997 targeting primarily declared rare flora populations. Several of these targets occur within the Montane mallee thicket TEC, notably targets on Yungemere, South-east Ellen Peak, Mt Hassell, Mt Success and Mt Trio. Phosphite has been applied to these targets at rate of up to 24 kg / ha every two to three years. In populations recently burnt (sites burnt in 2000) phosphite has been applied at 12 kg / ha annually. Monitoring has occurred at these targets to evaluate the effectiveness of phosphite application. At South-east Ellen Peak, there was 95% survival of *Banksia brownii* plants within a sprayed quadrat from 1998 to 2000. This compares with 60 to 70% survival of the same species from 1997 to 2000 on the slopes of Mt Success in both sprayed and non-sprayed quadrats. On Mt Trio there has been 70% survival of *Gastrolobium luteifolium* plants in quadrats from 2001 to 2003.

The rate of spread of *P. cinnamomi* along dieback fronts typically ranges from 0.7 to 2.3 m per annum in South Coast plant communities in sites with gentle slopes (Grant and Barrett 2003). Considerably higher rates of up to 250 m per annum down-slope have been observed in the Stirling Range. On Mt Hassell, the rate of spread of the disease front upslope in sprayed vegetation was a mean of 7.6 cm per annum from 2000 to 2003. On Yungemere, down-slope rate of spread in a small circular infestation averaged 15-25 cm per annum from 2000 to 2002 but by 2003 the infestation had escaped several metres downhill. Therefore, control of *P. cinnamomi* by phosphite application has been effective at some sites (eg Barrett 2003) but less so at others such as Yungemere. This variability may be related to site characteristics including soils, topography, hydrology, fire history and species composition. While phosphite may be relatively effective in reducing root to root spread of the pathogen, on slopes with considerable water flow zoospores may be readily transmitted down slope after rainfall events and infection may spread more rapidly. Altered hydrology after fire may also exacerbate disease spread (M. Grant; G. Freebury personal communication[4]). Furthermore, it is possible that in this plant community phosphite may be relatively ineffectual in key component species, such as certain members of the Proteaceae, thus providing a weak link in disease control (B. Shearer pers comm.).

Long term monitoring is required to determine the effectiveness of phosphite application. There is also a need to further refine phosphite application techniques and determine reasons for loss of disease control. Annual application may be required to improve its effectiveness.

- **Inappropriate fire**

Fire has a significant effect on vegetation composition in Mediterranean ecosystems. The impact of fire on habitat is directly related to the frequency, timing, extent and intensity of the fire. It is likely that the fire regime in the area has been modified since European settlement with hot extensive burns becoming more frequent. Since the late 1980s, there have been a series of extensive fires in the Stirling Range National Park affecting various occurrences of the Montane mallee thicket community (1987, 1991, 1996, 1997 and 2000). In 2000, almost one third of the Park was burnt in two separate wildfires. The eastern section of the Park had been burnt nine years previously in 1991. In general, these fires have been notable for the intensity and homogeneity of impact leaving few unburnt patches. There have been three major fires in the eastern Stirling Range in the last 25 years. These occurred in February 1972, April 1991 and October 2000 with an anecdotal record of a fire in the late 1950s. Species and community response to fire is variable and no fire regime is optimal for all species. While low frequency fires may also lead to population decline due to senescence, the current fire history in the Stirling Range National Park suggest that high frequency, intense fires constitute the greatest risk for driving population decline and extinction. 'Vital attributes', as described by Noble and Slatyer (1979), of individual plant species may be used to identify species sensitive to frequent fire such as obligate seeders, in particular serotinous species. The primary juvenile period of the slowest maturing individual should be considered when defining the upper threshold for fire frequency (Bradstock and Connell 1988). Slow growth rates observed on mountain tops (Barrett 1996) suggest that the time for many species to reach maturity in this community may be relatively high compared with lowland plant communities. It has been suggested that there is a clear dichotomy in the fire sensitivity of species occupying the wet gullies and thickets of upland areas and those occupying the seasonally dry lowland mallee-heath (Main and Gaull 1993;

[4] Malcolm Grant, Senior Operations Officer – Nature Conservation, CALM Albany Work Centre, Ravensthorpe Office

Friend and William 1993) with the upland areas requiring a longer fire-free interval of up to 25 years. In summary, fire needs to occur at appropriate intervals taking into consideration season and intensity to maintain the composition and structure of this plant community.

Key fire sensitive species in the community include the obligate seeder species *Banksia solandri, Banksia brownii, Lambertia fairallii, Isopogon latifolius, Dryandra concinna* and *Banksia oreophila*. A fire interval of at least double the primary juvenile period has been recommended (Gill and Nicholls 1989), which for example in the case of *Banksia brownii* would be 7 x 2 = 14 years based on a time to first flowering of seven years recorded on Mt Hassell. However, at 12 years post fire on Yungemere cone production for both *B. brownii* and *B. solandri* was still at very low levels (Table 1).

Similarly, an earlier study on the reproductive potential of *B. brownii* in 1993 documents a mean cone production of 2.3 per plant, viable seed per cone of 1.9 and mean seed per plant of 5.8 at 13 years post-fire on Mt Hassell (Galea and Lamont 1993). Therefore it is possible that longer than double the juvenile period may be required between fires in this community. Preliminary data on fruit production at various time since fire in key fire sensitive species in the community is shown in Table 1 (Barrett unpub.) and indicates that considerable fire free intervals are essential to replenish seed banks although further research is required to determine mean seed production per plant and the minimum seed bank required to replace populations.

Table 1. **Mean fruit production per plant in six obligate seeder species in the Montane mallee thicket community at various times since fire** (n = 20 or 30 plants per species).

Species	**Time since fire (years)**		
	6	**7**	**12**
Site	**(**Talyuberlup, SW Gog)	(Mt Hassell)	(Yungemere, Wedge Hill, Success)
Banksia brownii	-	0.0	0.6
Banksia solandri	0.0-0.1	0.6	0.7-1.3
Isopogon latifolius	0.1	0.8	3.9
Dryandra concinna	4.1	-	-
Banksia oreophila	-	0.7	-
Lambertia fairallii		0.4	6.2

The need to ensure a sufficient fire-free interval in this community is further supported by data showing a dramatic reduction in densities of *B. brownii* and *L. fairallii* after fires in 1991 and 2000 on Mt Success and South-east Ellen Peak. Mean numbers of *B. brownii* individuals in quadrats on Mt Success fell from 2.3 / m^2 pre fire to 0.05 / m^2 post-fire while densities of *Lambertia fairallii* fell from 7.5 / m^2 to 0.1 / m^2 (Barrett unpub.) On South-east Ellen Peak *B. brownii* densities fell from 2.4 / m^2 to 0.2 / m^2 while a small population of *L. fairallii* became locally extinct post-fire (Barrett unpub). Further study of the fire ecology of this community is required.

A Draft Fire Management Strategy has been developed for the Stirling Range NP (Barrett *et al.* 2004). The strategy recommends that demographic processes and life history attributes (vital attributes) be used to identify fire sensitive species within each fire 'cell' and to determine the minimal tolerable fire frequency for these species. It also identifies threatened species and ecological communities and recommends that the core mountain areas (corresponding to occurrences of this community) be designated as "no planned burn" areas for the duration of the Master Burn Plan (valid till 2009). The strategy recommends the judicious use of prescribed fire within the lowland areas to protect the high conservation values of the Montane mallee thicket community. Use of such planned fire requires monitoring. The Stirling Range Management Plan (1999) also recommends the use of planned fire to maintain biological diversity, monitoring of planned fire and research into fire ecology.

- **Recreational impacts**

The Stirling Range has a long history of recreational use. In 1913 the Stirling Range National Park was created and by 1920 the Stirling Range Tourist Association had developed access roads to the area. The main

threat posed by walkers is the introduction of *P. cinnamomi* to disease free areas on muddy boots (Gillen and Watson 1993). Other negative impacts that may result from recreational activity include braiding and side path formation, path erosion, campfire remains, litter and nutrient enrichment of soils.

Mountains supporting the community with tracks include Mt Trio, Mt Hassell, Toolbrunup, Talyuberlup and Magog. All of these mountains have extensive areas of infestation associated with these tracks with the exception of Toolbrunup where a woodland plant community occurs adjacent to the walk-trial except closer to the summit. Mondurup has a track but this was closed to visitation to prevent introduction of *P. cinnamomi* to the healthy summit ridge in 1999. Conversely, Toll Peak appears to be non-infested and yet until the mid 1980s there was a track that passed through a *P. cinnamomi* infested area and up to the summit.

Several mountains in the community such as Barnett Peak, The Abbey, Henton Peak, Twin Hills, Hosteller Hills, Yungemere Peak and Mt Success occur in sections of the park that are rarely visited by bushwalkers. The only other possible human vector to these isolated yet infested sites would be army personnel transported by helicopter for remote survival camping, mainly in the 1970s and 1980s (J Watson personal communication). Where isolated spot infestations occur mid to upper slope in the apparent absence of infestation of the summit area (for example Yungemere, Hosteller Hills, Wedge Hill) it is possible that vertebrate species such as quokka (*Setonix brachyurus*), quenda (*Isoodon obesulus*) or echidna (*Tachyglossus aculeatus*) may be responsible for spread of the pathogen. Significant activity of these species has been observed with associated soil disturbance and spot infestations on Yungemere (S. Barrett unpublished data, G. Freebury Personal communication)

Yungemere, Wedge Hill, Hostellers Hills, Mondurup and Little Mondurup occur within 'Special Conservation Zones' and require a permit for foot access under dry soil conditions only (Allan and Herford 1999). Magog, Gog, Tayuberlup, Barnett, the Abbey, the ridge southwest of Gog, Henton Peak, Twin Hills, Mt Trio, Toolbrunup and Mt Hassell and Toll Peak occur within areas zoned 'natural environment' which allows for facilities such as marked paths with trail head information and designated campsites. Of these, the ridge southwest of Gog and Toll Peak have the most intact occurrences of the community. As the ridge southwest of Gog is close to and opposite the Stirling Range Lookout on Stirling Range Drive, an area of high visitation, there is a risk that disease may be inadvertently introduced to the healthy western section of this ridge. Baby Barnett occurs within an area zoned 'recreation', however, an old track to the summit is no longer maintained. Mt Success and South-east Ellen Peak occur within the 'wilderness' zone, which permits pedestrian access only and unmarked walking routes.

- **Herbivory**

Young plants are attractive to herbivores such as rabbits and quokka and the impact of grazing in the early post-fire years in this community is unknown. Observations on Bluff Knoll in the Montane heath and thicket TEC suggest that grazing by one or both of these herbivores is having an adverse impact on the health of several members of the community including threatened species. There is evidence of rabbits on Mt Trio and grazing of the threatened species *Leucopogon gnaphalioides* has been observed on Toolbrunup (S. Barrett unpublished data.).

- **Weeds**

There is little evidence of significant weed infestations in the community. There are some minor weed occurrences near the summit areas of a few mountains such as Toolbrunup and Barnett Peak where there are exposed areas of soil adjacent to rocky outcrops. Weeds present include *Aira* sp., *Avena* sp., *Briza minor, Lolium* sp., *Bellardia trixago, Hypochoeris glabra*, *Pseudognaphalium luteoalbum*, *Sonchus oleraceus* and *Ursinia anthemoides*.

- **Climate change**

Montane plant communities may be particularly vulnerable to climate change because of limited adaptive capacity, their fragmented nature and limited topographic range for species migration. The Draft Western Australian Greenhouse Strategy (Western Australian Greenhouse Taskforce 2003) recommends the establishment of research sites to monitor changes to terrestrial ecosystems in the South West as well as

biodiversity response modelling to investigate the potential vulnerability of Western Australian plants to climate change. The Montane mallee thicket TEC would be an appropriate community for such studies due to the refugial nature of its habitat.

1.12 Guide For Decision-Makers

Section 1.11 above provides details of current and possible future threats. Management of the Stirling Range National Park should continue to take potential impacts on the community into consideration.

1.13 Conservation status

The Montane mallee thicket of the Stirling Range meets the following criteria for Endangered (EN) ecological communities:

B) Current distribution is limited, **and**:

i) geographic range and number of discrete occurrences, and area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short term future (within approximately 20 years);
iii) there may be many occurrences but total area is small and all or most occurrences are small and/or isolated and very vulnerable to known threatening processes.

1.14 Strategy for recovery

To undertake recovery actions for the Montane mallee thicket community that aim to maintain the overall health of intact and relatively intact areas of the community and reduce the level of threat to these occurrences.

To conduct appropriate research into the ecology of the community to develop further understanding about the management actions required to maintain or improve the condition of the community.

2. RECOVERY OBJECTIVE AND CRITERIA

IRP Objective(s): To maintain the overall health of selected areas of the Montane mallee thicket community and reduce the level of threat to these representative areas, so that the community does not move into a higher category of threat during the life of this plan.

Criteria for success:
Maintenance of the diversity and composition of native species in those occurrences of the community that are intact or relatively intact in terms of structure, species diversity and composition.

Reduction in the impact of *Phytophthora cinnamomi* on the community as measured by improved survival of *Phytophthora cinnamomi* susceptible taxa in infected areas or a reduction in the rate of spread of dieback fronts into disease-free areas.

Criteria for failure:
A sustained or increased level of modification of occurrences of the community as measured by declining survival of *Phytophthora cinnamomi* susceptible taxa in infected areas.

Significant impact of *Phytophthora cinnamomi* in areas that are relatively intact in terms of species composition

3. RECOVERY ACTIONS

Existing Recovery Actions

The recovery team is as for the TEC “Montane heath and thicket of the South West Botanical Province, above approximately 900 m above sea level (Eastern Stirling Range Montane heath and thicket

Community)". The team includes Representatives from CALM's Albany Work Centre, Species and Communities Branch (SCB), Science Division, Shire Representatives and community representatives. The Recovery Team reports annually on progress with recovery work to CALM's Corporate Executive.

Future Recovery Actions

The following recovery actions are roughly in order of descending priority; however this should not constrain addressing any of the priorities if funding is available for 'lower' priorities and other opportunities arise.

3.1 Coordinate recovery actions

The East Stirling Range Montane Community Recovery Team (ESRMCRT) will continue to coordinate recovery actions for the *Montane Mallee thickets of the Stirling Range* TEC and the *Eastern Stirling Range Montane Heaths and Thickets* TEC. They will include information on progress in their annual report to CALM's Corporate Executive and funding bodies.

Responsibility: Albany District and SCB through the ESRMCRT
Cost: $500 pa
Completion date: Ongoing

3.2 Assess and map the extent and condition of the community including the extent of *Phytophthora cinnamomi* infestation and the presence of other threats

Comprehensive mapping of non-infested and 'protectable' areas is essential for management as well as an assessment of any additional threats such as recreational impacts or grazing. Accurate mapping of *P. cinnam*omi will require the use aerial photography combined with ground truthing.

Responsibility: CALM (Albany Work Centre).
Cost: $15,000 in Year 1, then $3,000 in Years 2 and 3.
Completion date: Year 3

3.3 Survey for additional occurrences of the community

Further survey is required to determine whether additional occurrences of the community exist

Responsibility: CALM (Albany Work Centre).
Cost: $2000 in Years 1, 2 and 3
Completion date: Year 3

3.4 Rank areas of community for urgency of recovery actions and identify key actions

Occurrences of the community must be ranked in terms of their condition and conservation values to enable recovery efforts to be focussed on those priority areas.

Responsibility: CALM (Albany Work Centre).
Cost: $500
Completion date: Year 3

3.5 Control of *P. cinnamomi*

Apply phosphite to key occurrences of the community to reduce the spread of *P. cinnamomi* in and to priority occurrences and to increase survival of threatened species in infested areas. Manage access to *P. cinnamomi* free occurrences via tracks and fire breaks and ensure appropriate hygiene protocols are adhered to.

Responsibility: CALM (Albany Work Centre).

Cost: $30,000 per annum
Completion date: Ongoing

3.6 Conduct research to develop an understanding of the population dynamics of *P. cinnamomi* in Stirling Range soils, of factors influencing susceptibility to the disease and develop improved phosphite application techniques

Conduct research to improve the understanding of factors critical in the development, survival, dispersal and infection of *Phytophthora cinnamomi* in soils of the Stirling Range. In particular determine the effects of site and season on population levels of *P. cinnamomi*, factors influencing susceptibility to the disease and factors influencing the effectiveness of phosphite. Develop improved phosphite application techniques.

Responsibility: CALM (Albany Work Centre and Science Division).
Cost: $20,000 in Year 1, $10,000 per annum Years 2 and 3.
Completion date: Year 3

3.7 Monitor the rate of spread of *P. cinnamomi* in or adjacent to occurrences of the community and the effectiveness of phosphite application

Use both on-ground monitoring and aerial photography as outlined in 3.2 to monitor the impact and spread of *P. cinnamomi* to prioritise areas for phosphite application as well as monitoring the effectiveness of phosphite in sprayed areas.

Responsibility: CALM (Albany Work Centre).
Cost: $8,000 per annum
Completion date: Monitoring ongoing

3.8 Obtain biological and ecological information, in particular information on the fire ecology of the community

There is a need for research into recovery of the community from fire, and to determine the implications of findings for management. This information will determine the minimum tolerable fire frequencies of key fire sensitive species in the community.

Responsibility: CALM (Albany Work Centre and Science Division).
Cost: $8,000 in Year 1, then $3,000 per annum in Year 2 and 3.
Completion date: Year 3

3.9 Establish long term monitoring to quantify changes in community species composition and structure caused by *Phytophthora cinnamomi* infestation

Long term monitoring is necessary to determine changes in the composition and structure of the TEC over a period of 20 years or more in relation to the disease cycle (see Weste *et al*. 2002).

Responsibility: CALM (Albany Work Centre and Science Division).
Cost: $8,000 in Year 1
Completion date: Ongoing

3.10 Establish long term monitoring to quantify changes in community biodiversity due to climate change

Establishment of research sites to monitor potential changes in biodiversity in the TEC due to climate change
Responsibility: CALM (Albany Work Centre and Science Division).
Cost: $8,000 in Year 1
Completion date: Ongoing

3.11 Develop and implement a fire management strategy

A fire management strategy for the community needs to be part of a broader strategy for the Stirling Range National Park including the Montane thicket and heath TEC as well as protecting threatened fauna and flora. The use of planned fire to create a mosaic of fire ages in lowland areas may be used to ensure longer fire free intervals in upland areas. A draft fire management strategy for the Stirling Range National Park including a fire history map has been completed. Pre- and post-fire monitoring of planned fire is recommended to allow for adaptive management. A fire history map of the occurrences is to be updated annually.

Responsibility: CALM (Albany Work Centre).
Cost: $10,000 per annum
Completion date: Ongoing

3.12 Preserve germplasm of key species in the community

Preservation of germplasm is essential to guard against the possible extinction of wild populations. Seed and cuttings can be used to propagate plants for future translocations. Seed is required from a range of occurrences to maximise the genetic diversity of *ex situ* material.

Responsibility: CALM (Science Division and Albany Work Centre).
Cost: $10,000 in Year 1, then $5,000 per annum in Year 2 and 3
Completion date: Ongoing

3.13 Promote awareness of the community

The importance of biodiversity conservation and the need for the long-term protection of this TEC will be promoted to the public through poster displays and the local print and electronic media. Formal links with local naturalist groups and interested individuals will also be encouraged. A bush-book describing the Stirling Range flora which features several species from this community is to be published and will reference this TEC.

Responsibility: Recovery Team and CALM (Albany Work Centre).
Cost: $1,000 per annum
Completion date: Ongoing

3.14 Incorporate strategies to protect the community into the Park Management Plan when it is reviewed

Responsibility: CALM (Albany Work Centre).
Cost: $500
Completion date: Review date of Mangement Plan

3.15 Write full Recovery Plan if required

At the end of the five-year term of this interim Recovery Plan, the need for further recovery will be assessed as will the need for a full Recovery Plan or to update this IRP.

Responsibility: CALM (Albany Work Centre).
Cost: $17,500 in Year 5 if required
Completion date: Year 5

4.0 TERM OF PLAN

This IRP will operate from December 2004 for 5 years but will remain in force until withdrawn or replaced

5.0 REFERENCES

Aberton MJ, Wilson BA and Cahill MJ (1999) The use of potassium phosphonate to control *Phytophthora cinnamomi* in native vegetation at Anglesea, Victoria. *Australasian Plant Pathology* 28, 225-234**.**

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

Allan & Herford (Eds) (1999) Stirling Range and Porongurup National Parks Management Plan 1999-2009. Management Plan No 42. Department of Conservation and Land Management for the national Parks and Nature Conservation Authority, Perth, Western Australia.

Barrett S (1996) Biological survey of mountains in southern Western Australia. Department of Conservation and Land Management, Perth.

Barrett S (2000) Montane Heath and Thicket of the South West Botanical province, above approximately 900 m above seas level (Eastern Stirling Range Montane Heath and Thicket Community)Interim Recovery Plan 1999-2002, Department of Conservation & Land Management, WA Threatened Species and Communities Unit.

Barrett 2003 Monitoring of aerial phosphite applications for the control of *Phytophthora cinnamomi* in the Albany District. In Proceedings of *'Phytophthora* in forests and natural ecosystems, (2nd International IUFRO Working party, Albany).

Barrett, S.R Broomhall, G. Comer,S, Freebury, G. and Grant, M. (2004) Draft Fire Management Strategy for the Stirling Range National Park. Department of Conservation and Land Management Unpublished Report

Barrett S and Gillen K (1997) Mountain protected areas of south Western Australia. *PARK* **7,** 35-42

Beard JS (1979) The vegetation of the Albany & Mt. Barker areas, Western Australia [kit]: map and explanatory memoir, 1:250,000 series. Vegmap, Perth

Bradstock RA and Connell MA (1988) Demography of woody plants in relation to fire: *Banksia ericifolia* L.f and *Petrophile pulchella* (Schrad) R.Br. *Aust. J of Ecology* **3**: 505-

Courtenay J **(**1993) Ch.2 Climate in "Mountains of Mystery". Dept. of Conservation and Land Management, Perth

Friend, G. & Williams, M. (1993). Fire & Invertebrate Conservation in Mallee Heath Remnants. Final Report - World Wide Fund For Nature Australia Project P144. Dept. of Conservation & Land Management, Perth.

Galea, H. and Lamont, B. (1993). Population ecology of the rare and endangered *Banksia brownii*. Consultancy report to the Department of Conservation and Land Management. School of Environmental Biology, Curtin University of Technology

Gill AM and Nicholls AO (1989) Monitoring fire-prone flora in reserves for nature conservation. In 'Fire Management on Nature Conservation Lands'. (Eds Burrows N, McCaw L and Friend G) pp137-151. 1/89.

Department of Conservation & Land Management (1999) Stirling Range and Porongurup National Parks: Management Plan. Perth.

Gillen K and Watson JR (1993) Controlling *Phytophthora cinnamomi* in the moutains of south Western Australia. *Australian Ranger* **27**: 18-20.

Grant M and Barrett S (2003) The distribution and impact of *Phytophthora cinnamomi* Rands in the south coast region of Western Australia. In Proceedings of *'Phytophthora* in forests and natural ecosystems, (2nd International IUFRO Working party, Albany).

Hopkins AJM, Keighery GJ and Marchant NG (1983) Species-rich uplands of south-western Australia. *Proceedings Ecological Society of Australia* **12,** 15-26

Keighery GJ (1993) Chapter 6 Plant communities in "Mountains of Mystery". Dept. of Conservation and Land Management, Perth.

Komorek B, Shearer BL, Smith B, Fairman RG (1997) The control of *Phytophthora* in native plant communities. In 'Control of *Phytophthora* and *Diplodina* Canker in Western Australia. Final Report to the Threatened Species and Communities, Biodiversity Group, Environment Australia'. (Ed. D Murray) pp.1-59. (Department of Conservation and Land Management: Perth)

Leighton, S. (1993) Chapter 4 Aboriginal history in "Mountains of Mystery". Dept. of Conservation and Land Management, Perth.

Main, B.Y. & Gaull, K. (1993). Response of trapdoor spiders to fire in the Stirling Range. Unpublished Report to the Dept. of Conservation & Land Management, Perth.

Muhling PC and Brakel AT (1985) Mount Barker-Albany. Geological Survey of Western Australia: 1:250,000 Geological Series Explanatory Notes. Geological Survey of Western Australia.

Nicholls O (1998). Scope Item 7: Impacts of dieback-induced vegetation changes on native faunal communities in south-west Western Australia. In 'Control of *Phytophthora* and *Diplodina* Canker in Western Australia'. Final Report to the Threatened Species and Communities, Biodiversity Group, Environment Australia' (Ed. D. Murray) pp.21-32. (Department of Conservation and Land Management: Perth.)

Noble IR and Slatyer RO (1979) The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. *Vegetatio* **43**, 5-21.

Pignatti, E., Pignatti, S. & Lucchese, F. (1993). Plant Communities of the Stirling Range, Western Australia. *J. Veg. Sci*. **4**: 477-488

Shearer BL and Tippett JT (1989) Jarrah dieback, the dynamics and management of *Phytophthora cinnamomi* in the jarrah (Eucalyptus marginata) forest of south-western Australia. Research Bulletin No.3. (Department of Conservation and Land Management: Perth).

Shearer BL, Fairman RG (1991) Control of *Phytophthora* species in native communities with phosphorous acid. In 'Proceedings of the Conservation Biology in Australia and Oceania Conference'. p. 72. (University of Queensland: Brisbane)

Shearer BL, Fairman RG (1997) Foliar application of phosphite delays and reduces the rate of mortality of three *Banksia* species in communities infested with *Phytophthora cinnamomi* . In 'Proceedings of the 11th Biennial Conference of the Australasian Plant Pathology Society'. p. 180. (Australasian Plant Pathology Society: Perth)

Weste, G. and Marke, G.C. (1987).The biology of *Phytophthora cinnamomi* in Australian forests. *Annual Review of Phythopathology*. 25, 207-229.

Weste G, Brown K, Kennedy J, Walshe T (2002) *Phytophthora cinnamomi* infestation – a 24-year study of vegetation change in forests and woodlands of the Grampians, Western Victoria. *Australian Journal of Botany* **50**, 247-274.

Noble IR and Slatyer RO (1979) The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. *Vegetatio* **43**, 5-21.

Western Australian Greenhouse Task Force (2003) Draft Western Australian Greenhouse Strategy

Wilkinson CJ, Holmes, JM, Dell B, Tynan KM, McComb JA, Shearer BL, Colquhuon IJ, Hardy GEStJ (2001) Ability of phosphite applied in a glasshouse trial to control *Phytophthora cinnamomi* in five plant species native to Western Australia. *Australasian Plant Pathology* **30**, 343-351.

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

Wills RT and Keighery GJ (1994) Ecological impact of plant disease on plant communities. *Journal of the Royal Society of Western Australia* **77**, 127-132

Wilson B.A., Newell, G., Laidlaw, W.S. and Friend, G. (1994). Impact of plant diseases on faunal communities. *J. Roy. Soc. W.A.* **77,** 139-144.

Appendix 1: Threatened and priority taxa in occurrences of the Montane mallee thicket community

The Abbey
Gastrolobium crenulata capitate, Gonocarpus rudis (P2), *Adenanthos filifolius, Andersonia echinocephala, Isopogon latifolius, Sphenotoma* sp. Stirling, *Stylidium verticillatum* (P3), *Darwinia hypericifolia, Dryandra concinna, Dryandra hirsuta, D. foliolata, Banksia solandri, Velleia foliosa* (P4)

Baby Barnett
Andersonia echinocephala, Dryandra hirsuta, Hibbertia helianthemoides, Hypocalymma phillipsii, Isopogon latifolius (P3), *Banksia solandri, Darwinia hypericifolia, Dryandra concinna, Dryandra foliolata, Muiriantha hassellii* (P4)

Barnett Peak
Sphenotoma drummondii (DRF)**,** *Acacia veronica, Adenanthos filifolius, Dryandra hirsuta, Isopogon latifolius, Andersonia echinocephala, Hypocalymma phillipsii, Hibbertia helianthemoides, Sphenotoma* sp. Stirling, *Stylidium verticillatum* (P3), *Banksia solandri, Dryandra foliolata, Darwinia hypericifolia* (P4)

Mt Hassell
Banksia brownii (DRF), *Gastrolobium vestita, Gastrolobium crenulata capitate* (P2), *Adenanthos filifolius, Isopogon latifolius, Sphenotoma* sp. Stirling, *Stylidium verticillatum, Dryandra hirsuta* (P3), *Banksia solandri, Dryandra foliolata, Dryandra concinna, Darwinia hypericifolia* (P4)

Henton Peak
Requires further survey

Hostellers Hills
Darwina wittwerorumi (DRF*), Andersonia echinocephala, Dryandra hirsuta, D. seneciifolia, Hibbertia argentea, Isopogon latifolius, Sphenotoma* sp. Stirling (P3), *Banksia solandri, Dryandra concinna, Dryandra foliolata, Muiriantha hassellii,* (P4)

Mt Gog
Acacia imparilis (P2), *Andersonia echinocephala, Dryandra hirsuta, D. senecifolia, Hypocalymma phillipsii, Sphenotoma* sp. Stirling (P3), *Banksia solandri, Calothamnus crassus, Darwinia hypericifolia, Dryandra concinna, Dryandra foliolata, Eucalyptus ligulata* subsp. *stirlingica, Muiriantha hassellii, Velleia foliosa* (P4)

Little Mondurup
Sphenotoma drummondii (DRF), *Dryandra ferruginea* subsp. *pumilo* (P2), *Adenanthos filifolius, Hypocalymma phillipsii, Isopogon latifolius* (P3)**,** *Banksia solandri, Darwinia macrostegia* (P4)

Mondurup
Leucopogon gnaphalioides, Sphenotoma drummondii (DRF)**,** *Adenanthos filifolius, Dryandra hirsuta, Isopogon latifolius, Andersonia echinocephala, Sphenotoma* sp. Stirling (P3), *Banksia solandri, Dryandra foliolata, Dryandra concinna, Darwinia macrostegia* (P4)

Ridge southwest of Gog
Darwina wittwerorum, Lambertia fairallii (DRF*), Dryandra ferruginea* subsp. *pumilo* (P2). *Isopogon latifolius, Andersonia echinocephala, Dryandra hirsuta, Hypocalymma phillipsii, Hibbertea argentea, Sphenotoma* sp. Stirling, *Xanthosia collina* (P3), *Dryandra foliolata, D. concinna, B. Solandri, Muiriantha hasselli* (P4)

Talyuberlup
Acacia imparilis, Lasiopetalum dielsii (P2), *Isopogon latifolius, Andersonia echinocephala, Dryandra hirsuta, Hypocalymma phillipsii* (P3), *Dryandra foliolata, D. concinna B. solandri, Darwinia hypericifolia* (P4)

Mt Magog
Sphenotoma drummondii (DRF), *Andersonia echinocephala, Dryandra foliolata, D. concinna, Hypocalymma phillipsii, Isopogon latifolius, Sphenotoma* sp. Stirling (P3*) Banksia solandri* (P4)

South-east Ellen Peak
Banksia brownii, Daviesia obovata, Lambertia fairallii (DRF), *Andersonia echinocephala* (P3), *Banksia solandri* (P4).

Toll Peak
*Andersonia echinocephala, Adenanthos filifolius (P3)***,** *Banksia solandri, Muiriantha hasselli, Darwinia lejostyla* (P4)

Toolbrunup
Leucopogon gnaphalioides, Sphenotoma drummondii (DRF), *Gastrolobium vestita, Gastrolobium crenulata capitata, Spyridium montanum* (P2), *Lasiopetalum dielsii* (P2), *Calothamnus crassus* (P4)

Mt Trio
Gastrolobium luteifolium, Sphenotoma drummondii (DRF) *Gastrolobium crenulata capitate, Gonocarpus rudis, Spyridium montanum* (P2), *Adenanthos filifolius, Andersonia echinocephala, Sphenotoma* sp. Stirling (P3), *Dryandra foliolata, Darwinia lejostyla, D. Hirsuta, Banksia solandri* (P4)

Twin Hills
Banksia solandri (E. Hickman Personal communication.) requires survey

Mt Success
Banksia brownii, Daviesia obovata, Lambertia fairallii (DRF*), Daviesia mesophylla* (P2), *Isopogon latifolius, Andersonia echinocephala, Hypocalymma phillipsii, Sphenotoma* sp. Stirling (P3), *Dryandra concinna, D. hirsuta, Dryandra plumosa* subsp. *denticulata, Banksia solandri, Darwinia lejostyla, Muiriantha hassellii* (P4)

Wedge Hill
Banksia brownii, Daviesia obovata, Sphenotoma drummondii (DRF), *Isopogon latifolius, Andersonia echinocephala, Hypocalymma phillipsii, Hibbertia argentea, Sphenotoma* sp. Stirling (P3), *Dryandra concinna, D. hirsuta, Eucalyptus ligulata* subsp. *stirlingia, Dryandra plumosa* subsp. *denticulata, Banksia solandri, Darwinia lejostyla* (P4)

Yungemere Peak
Banksia brownii, Lambertia fairallii (DRF), *Adenanthos filifolius, Isopogon latifolius, Andersonia echinocephala, Dryandra hirsuta, Hypocalymma phillipsii, Sphenotoma* sp. Stirling (P3), *Banksia solandri, Dryandra concinna, Dryandra foliolata* (P4)

Appendix 2: Summary of costs for each recovery action

Recovery Action	Year 1	Year 2	Year 3	Year 4	Year 5
Coordinate Recovery Actions	$ 500	$500	$500	$500	$500
Map the extent and condition of the community	$15,000	$3,000	$3,000	$3,000	$3,000
Additional survey	$ 2,000	$2,000	$2,000		
Rank occurrences for urgency of recovery actions	$ 500	-	-	-	-
Control of *P. cinnamomi*	$30,000	$30,000	$30,000	$30,000	$30,000
Research population dynamics of *P. cinnamomi*, susceptibility, phosphite application techniques	$20,000	$10,000	$10,000		
Monitor *P. cinnamomi* and phosphite application	$ 8,000	$8,000	$8,000	$8,000	$8,000
Conduct biological research (fire ecology)	$ 8,000	$3,000	$3,000		
Establish long-term monitoring for *P. cinnamomi* impact	$ 8,000				
Establish long-term monitoring for climate change	$ 8,000				
Implement fire management strategy	$10,000	$10,000	$10,000	$10,000	$10,000
Preservation of germplasm	$ 10,000	$5,000	$5,000	-	-
Promote awareness of the community	$ 1,000	$1,000	$1,000	$1,000	$1,000
Incorporate strategies into the Park Management Plan	-	-	-	-	$500
Write full Recovery Plan, if required	-	-	-	-	$17,500
Total	$121,000	$72,500	$72,500	$52,500	$70,500

Totals

Year 1	$121,000
Year2	$ 72,500
Year 3	$ 72,500
Year 4	$ 52,500
Year 5	$ 70,500
OVERALL TOTAL	$389,000

Fig. 1a Occurrences of Montane mallee thicket TEC west of Chester Pass, healthy areas in green, modified by *Phytophthora cinnamomi* in red

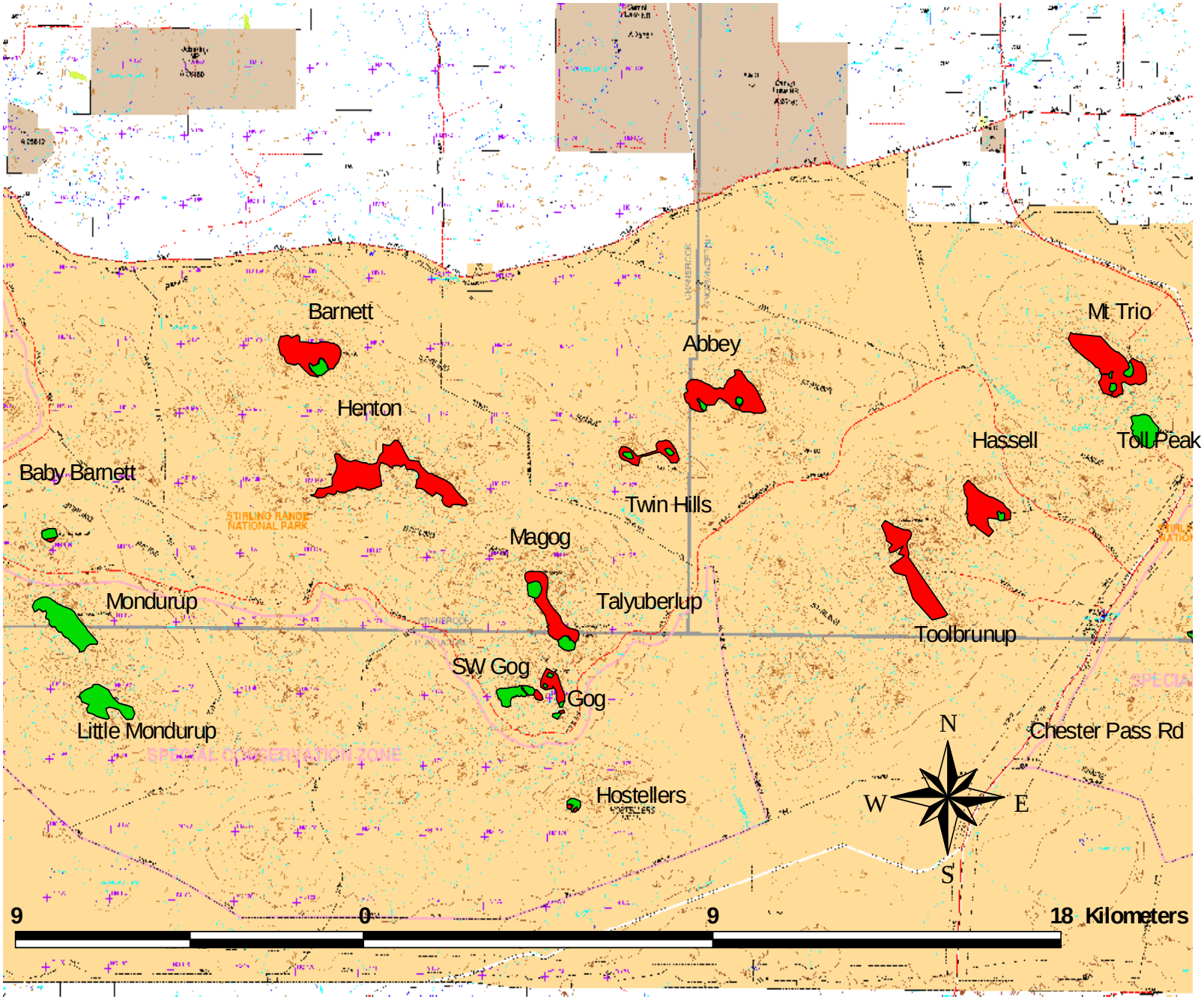

Fig. 1b Occurrences of Montane thicket TEC east of Chester Pass, healthy areas shown in green, modified by *Phytophthora cinnamomi* in red