

## Interim Recovery Plan No. 370

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)

**2016-2021**



Department of  
**Parks and Wildlife**



October 2016

# Foreword

Interim Recovery Plans (IRPs) are developed within the framework laid down in Department of Parks and Wildlife Policy Statement No. 35 (DPaW 2015a) and Department of Parks and Wildlife Corporate Guideline No. 35 (DPaW 2015b).

This Interim Recovery Plan replaces plan number 52 '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) 1999-2001' by S. Barrett.

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

The department is committed to ensuring that 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 department's Director of Science and Conservation.

This IRP will operate from 4 December 2016 but will remain in force until withdrawn or replaced. It is intended that, if the ecological community is still listed as Threatened after five years, this Interim Recovery Plan will be replaced or updated.

This IRP was approved by the Director of Science and Conservation on 4 December 2016. The provision of funds identified in this IRP is dependent on budgetary and other constraints affecting the department, as well as the need to address other priorities.

Information in this IRP was accurate as at October 2016.

## **ACKNOWLEDGEMENTS**

This plan was prepared by Sarah Barrett. Cover photograph by Sarah Barrett.

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

Valerie English	Parks and Wildlife, Species and Communities Branch
Anne Cochrane	Parks and Wildlife, Science and Conservation Division

## **CITATION**

This Interim Recovery Plan should be cited as:

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# SUMMARY

**Name:** 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).

**Description:**

A heathland and dense shrub thicket with a number of endemic species that occupies the high peaks of the eastern Stirling Range, mountains that are effectively biological islands in a landscape of otherwise low relief. There are five occurrences of the TEC that cover a total area of about 330 ha. The TEC is found at altitudes of approximately 900 to 1090 m above sea level (a.s.l.) however extending to lower altitudes in two occurrences. Conditions are distinctively montane; with skeletal soils on quartzite, extremes of temperatures, high humidity and exposure, and occasional snowfalls. Several endemic and characteristic species within the community and the near absence of *Eucalyptus* species differentiate it from other plant communities in the range.

**Department of Parks and Wildlife Regions:** South Coast

**Department of Parks and Wildlife Districts:** Albany District.

**Local Government Authorities:** Gnowangerup.

**Conservation status:** The community is listed as a critically endangered TEC in WA, endorsed by the WA Minister for Environment, and listed as endangered under the EPBC Act.

**Habitat requirements:** This community occurs on shallow soils on quartzite on mountain summits from approximately 750 m above sea level (a.s.l.) to 1090 m a.s.l.

**Habitat critical to survival:** The critical habitat for this community is the montane habitat on which the community occurs.

The habitat critical to survival is: the area of occupancy of known occurrences; similar habitat adjacent to important occurrences (i.e. within approximately 200m) and remnant vegetation that surrounds or links several occurrences (this is to provide habitat for pollinators or to allow them to move between occurrences).

**Important occurrences:** Occurrences that provide for representation of the community across its geographic range and that can be managed for conservation and/or with conservation included in their purpose are considered important occurrences of this community.

**Affected interests:** All occurrences occur on lands managed by Parks and Wildlife.

**Indigenous interests:** An Aboriginal Sites Register is kept by the Department of Aboriginal Affairs, and lists one artifact/scatter site within the vicinity of the occurrences. Actions identify the intention to continue liaison with relevant groups, including Indigenous groups.

**Social and economic impacts and benefits:** The implementation of this recovery plan has the potential to have some social impact in relation to recreational use of the TEC. Recovery actions refer to continued liaison between stakeholders with regard to these areas.

**Related biodiversity impacts and benefits:** Two State-listed Priority Ecological Communities (PECs) (Coyanerup Wetland Suite and Montane Mallee Thicket of the Stirling Range) benefit from management actions such as disease and fire controls for this TEC.

Twelve Declared Rare Flora (DRF) are known from the community: *Andersonia axilliflora*, *Banksia brownii*, *Banksia montana*, *Darwinia collina*, *Darwinia nubigena*, *Darwinia squarrosa*, *Daviesia obovata*, *Deyeuxia drummondii*, *Lambertia fairallii*, *Latrobea colophona*, *Leucopogon gnaphalioides*, *Persoonia micranthera* and *Sphenotoma drummondii*; and 21 priority flora taxa also occur in the community. Recovery actions implemented to improve the quality or security of the community are also likely to improve the status of component species.

Five threatened fauna occur within the TEC: quokka (*Setonix brachyurus*), *Banksia montana* mealybug (*Pseudococcus markharveyi*), *Banksia brownii* plant-louse (*Trioza barrettae*), Robin's assassin spider (*Zephyrarchaea robinsi*), Bluff Knoll Atelomastix millipede (*Atelomastix tumula*); as well as the priority fauna *Bothriembryon glauerti* (P2).

**Term of plan:** The plan will operate from 2016 to 2021 but will remain in force until withdrawn or replaced. It is intended that after five years, the need for further recovery actions and the need for an updated recovery plan will be evaluated.

**IRP Objective(s):** To maintain or improve the overall condition of the 'Montane heath and thicket' community and reduce the level of threat.

**Criteria for success**

- 80% or more of the of priority areas covered by this interim recovery plan are maintained at the same condition rank or improved through actions implemented over the life of the plan, excluding effects of drying climate that are outside the scope of this plan.

**Criteria for failure:**

- Decline to a lower condition rank of 20% or more of the area of priority areas covered by this interim recovery plan through inaction or inappropriate actions, excluding effects of drying climate that are outside the scope of this plan.

**Summary of Recovery Actions:**

Co-ordinate recovery actions	Collect and store seed and other germplasm
Apply phosphite to priority areas	Develop and implement restoration strategy
Implement browsing management strategy	Protect community from physical trampling damage
Implement rabbit control program	Liaise with land managers and relevant Aboriginal communities
Implement a flora and vegetation monitoring program to evaluate the effectiveness of disease and herbivore management	Promote awareness
Implement disease hygiene procedures	Map critical habitat
Implement fire management strategy	Report on recovery plan implementation
Obtain additional ecological information	Review plan

# 1. BACKGROUND

## 1.1 History, defining characteristics and conservation significance

The unique nature of the ecosystem known as the Eastern Stirling Range Montane Heath and Thicket Community (referred to as 'Montane heath and thicket' from this point forward) was first described by Ludwig Diels in 1906 (Diels 2007), and subsequently in more detail by Pignatti *et al.* (1993) and most recently by Barrett (1996; 2000). The threatened ecological community is found at altitudes of approximately 900 to 1090 m above sea level (a.s.l.) however extending to lower altitudes of ~750m in two occurrences. Conditions are distinctively montane; with skeletal soils on quartzite, extremes of temperatures, high humidity and exposure, and occasional snowfalls. Several endemic and characteristic species within the community and the near absence of *Eucalyptus* species differentiate it from other plant communities in the Stirling Range.

A characteristic endemic species indicative of its distribution is *Andersonia axilliflora*, which is or was an abundant and dominant member of the community. Using *A. axilliflora* as an indicator, the community extends from the eastern limit of the Stirling Range, Ellen Peak (1012m), in four more or less continuous occurrences connected by downslope plant communities, to Coyanarup Peak (1045m) with a separate occurrence on the summit area of Mt Success (750m). The community is geographically restricted and occupies approximately 334 ha over 10 mountain summits (Ellen Peak, Pyungoorup, Bakers Knob, the Arrows, Isongerup, Moongoongoonderup, East Bluff, Bluff Knoll, Coyanerup and Mt Success) within a total extent of 644 ha and a lineal extent of 12.5 km (Appendix 1).

The community contains 13 declared rare (Threatened) and 21 Priority flora of which seven are endemic to the community

Long term monitoring and historical records show that the Montane Heath and Thicket has undergone substantial decline in recent decades (Keith *et al.* 2014; Barrett and Yates 2014). Current mapping of the Montane heath and thicket ecosystem shows that only 48 of 334 ha (14%) of the total historic distribution of the ecosystem remains relatively intact in terms of species composition (Barrett and Yates 2014).

A suite of fauna depend on the vegetation including two threatened invertebrate species that are dependent on threatened species in the community.

## 1.2 Biological and ecological characteristics

### **Habitat and Floristics**

#### **Physical environment**

The geology of the Stirling Range is comprised of sandstone and meta-sandstone (quartzite, shale and phyllite) (Seminiuk 1993). The 'Montane heath and thicket' grows on sandy clay loam to peaty clay loam soils with quartz and quartzite fragments. These soils are generally acidic (pH < 5) and have macro-nutrient and organic carbon concentrations that are high relative to the typically nutrient poor soils of the surrounding lowland plains (Barrett 2001). Plant growth is limited by low temperatures and high wind speeds that prevail for much of the year (Barrett 1996). The Stirling Range runs in an east-west direction and intercepts prevailing southerly winds from the Southern Ocean resulting in low-level stratified clouds draping over peaks on many days of the year. Long term climate data are not available for the ecosystem, but mean annual precipitation is estimated to be greater than 1000 mm (Courtney 1993). Although humidity is high for much of the year, the ecosystem is prone to fires spreading from the plains below during warmer, drier summer months (Barrett & Yates 2014).



### Biological environment

The ecosystem was described by Barrett (2000) as 'Montane heath and thicket' following Muir's Structural Classification (1977). The 'Montane heath and thicket' varies in height (from 0.5 to 2m) and cover (Projected Foliage Cover up to 80%) depending on abiotic factors including soil depth, aspect and fire as well as biotic factors such as disease and grazing. Taller thicket vegetation occurs on more sheltered sites on deeper soils. Characteristic plant taxa belong to the families Proteaceae, Myrtaceae, Fabaceae, Ericaceae, Apiaceae and Cyperaceae (Barrett and Yates 2014) (Appendix 2). Descriptions of the vegetation are found in Barrett (1996; 2000). The upper shrub stratum is characterised by *Andersonia axilliflora* (a key endemic species), *Kunzea montana*, *Beaufortia anisandra*, *Calothamnus montanus*, *Hakea florida*, *Banksia oreophila*, *B. solandri*, *B. concinna*, and *Sphenotoma* sp. Stirling Range and the lower sedge layer by *Lepidosperma* sp. Bluff Knoll robust, *Desmodium flexuosa* and *Tetraria* sp. Jarrah Forest. Annual and perennial graminoids and herbs are most abundant in the first five years after fire and then decline as the dominant shrub overstorey develops (Keith *et al.* 2014).

A range of proteaceous species were, or are, structurally significant and include *Banksia brownii*, *B. montana*, *B. concinna*, *B. oreophila*, *B. solandri* and *Hakea florida*. *Eucalyptus* species are notable for their absence from the community but occur at immediately lower altitudes. Species endemic to the community are *A. axilliflora*, *Banksia montana*, *Persoonia micranthera*, *Darwinia collina*, *Microcorys* sp. Stirling Range, *Stylidium* sp. Bluff Knoll and *Stylidium keigheryi*.

### Hydrology

There are no data available on surface or sub-surface water characteristics of the 'Montane heath and thicket' TEC.

### Related biodiversity impacts and benefits

Other TECs, Threatened and Priority flora and Threatened fauna either occur in the remnant vegetation containing this community or directly adjacent and may benefit from recovery actions implemented to improve the quality of the community.

Priority Ecological Communities (PECs) immediately adjacent to the 'Montane heath and thicket' TEC are 'Montane mallee thicket of the Stirling Range' (P1) and 'Coyanerup wetland suite' (P1).

A list of the 13 Threatened flora and 21 Priority taxa that occur with the community is presented in Table 1.

**Table 1: Threatened and priority flora that occur in the 'Montane heath and thicket' TEC**

\*= endemic to TEC

Species name	WA Conservation status and rank	Conservation status (EPBC Act 1999)
<i>Andersonia axilliflora</i>	T* (CR)	EN
<i>Banksia brownii</i>	T (CR)	EN
<i>Banksia montana</i>	T* (CR)	EN
<i>Darwinia collina</i>	T* (CR)	EN

<i>Darwinia nubigena</i>	T (EN)	VU
<i>Darwinia squarrosa</i>	T (VU)	VU
<i>Daviesia obovata</i>	T (EN)	EN
<i>Deyeuxia drummondii</i>	T (VU)	EN
<i>Lambertia fairallii</i>	T (CR)	EN
<i>Latrobea colophona</i>	T (CR)	-
<i>Leucopogon gnaphalioides</i>	T (CR)	EN
<i>Persoonia micranthera</i>	T* (CR)	EN
<i>Sphenotoma drummondii</i>	T (EN)	EN
<i>Dielsiodoxa tamariscinus</i>	P2	
<i>Gastrolobium leakeanum</i>	P2	
<i>Microcorys</i> sp. Stirling Range	P2*	
<i>Platysace</i> sp. Stirling Range	P2	
<i>Schoenus</i> sp. Stirling	P2	
<i>Spyridium montanum</i>	P2	
<i>Stylidium bellum</i>	P2	
<i>Stylidium keigheryi</i>	P2*	
<i>Stylidium oreophilum</i>	P2	
<i>Stylidium rosulatum</i>	P2	
<i>Stylidium</i> sp. Bluff Knoll	P2*	
<i>Adenanthos filifolius</i>	P3	
<i>Andersonia echinocephala</i>	P3	
<i>Hibbertia</i> aff. <i>argentea</i>	P3	
<i>Hypocalymma myrtifolium</i>	P3	
<i>Sphenotoma</i> sp. Stirling Range	P3	
<i>Actinotus rhomboideus</i>	P4	
<i>Banksia concinna</i>	P4	
<i>Banksia solandri</i>	P4	
<i>Boronia crenulata</i> var. <i>angustifolia</i>	P4	
<i>Muiriantha hassellii</i>	P4	

## Fauna

One threatened vertebrate fauna occurs within the TEC: quokka (*Setonix brachyurus*).

## Invertebrate fauna

The Stirling Range is notable for the prevalence of short range endemic and relictual invertebrate species (Harvey 2002; Moir *et al.* 2009; 2010, 2011, Rix and Harvey 2012). Within the 'Montane heath and thicket', are a number of endemic species of spiders, snails and millipedes. Threatened invertebrate fauna that occur within the TEC are: *Banksia montana* mealybug (*Pseudococcus markharveyi*), *Banksia brownii* plant-louse (*Trioza barrettae*), Robin's assassin spider (*Zephyrarchaea robinsi*), Bluff Knoll Atelomastix millipede (*Atelomastix tumula*), as well as the Priority 2 species *Bothriembryon glauerti*.

As part of a project to determine the co-extinction potential of plant-dwelling insects, mealybugs were collected on the foliage of *Banksia montana* (Proteaceae) in the Montane heath and thicket TEC. *Pseudococcus markharveyi* was discovered in 2007 through this targeted sampling of threatened plant species and non-threatened congeners. The host-specific and Critically Endangered hemipterans (the *Banksia brownii* plant-louse and the *Banksia montana* mealybug), are known to be dependent on *B. brownii* and *B. montana* plants, respectively, within the TEC for their life cycle. They feed exclusively on the sap of these plants; however, both hosts and dependent fauna are at risk of co-extinction (Moir et al. 2012; Gullan et al. 2013; Taylor & Moir 2014; Moir et al. 2016).

Microsatellites of the *Banksia brownii* plant-louse and *B. brownii* show high evolutionary congruency between plant and insect populations in Stirling Range and Albany Coastal populations (Moir et al. 2016). The extinction of divergent *B. brownii* populations within the TEC, therefore, is likely to have resulted in the extinction of divergent plant-louse populations. Up to half of the genetic diversity of *Banksia brownii* populations has been lost following the extinction of *B. brownii* along the eastern massif of the Stirling Range (Coates et al. 2015). Given the high degree of congruence between plant and plant-louse populations, the extinction of these eastern massif *B. brownii* populations by 2000 may have also resulted in the extinction of a very significant component of the divergent plant-louse population (Moir et al. 2016).

The Endangered plant *Leucopogon gnaphalioides*, another member of the TEC, has been found to host a distinctive assemblage of insects, despite other species of *Leucopogon* and members from the same plant family (Ericaceae) being found in close proximity. *Leucopogon gnaphalioides*' distinctive insect assemblage provide an example of a largely undescribed fauna (Moir & Vesk 2012).

### **Habitat critical to survival, and important occurrences**

The habitat critical to survival is: the area of occupancy of known occurrences; similar habitat adjacent to important occurrences (i.e. within approximately 200m) and remnant vegetation that surrounds or links several occurrences (this is to provide habitat for pollinators or to allow them to move between occurrences). Occurrences considered to be of highest importance are Bluff Knoll, Isongerup, East Bluff, Pyungoorup, Bakers Knob, Moongoongoonderup, Mt Success and Coyanerup.

### **1.5 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. This community is not listed under any specific international treaty, however, and therefore this interim recovery plan (IRP) does not affect Australia's obligations under any other international agreements.

### **1.6 Indigenous interests**

A search of the Department of Aboriginal Affairs (DAA) Aboriginal Heritage Sites Register revealed one site of Aboriginal significance in or adjacent to the TEC. This site is listed in the table below. The TEC also within the Stirling Range National Park is known to be a culturally significant site to Aboriginal people. Input and involvement has been sought through the South West Aboriginal Land and Sea Council (SWALSC) and DAA to determine if there are any issues or interests with respect to management of the TEC in the vicinity of these sites. Indigenous opportunity for future involvement in the implementation of the plan is included as an action in the plan. Aboriginal involvement in management of land covered by an agreement under the *Conservation and Land*



*Management Act 1984* is also provided for under the joint management arrangements in that Act, and will apply if an agreement is established over any reserved lands in which this TEC occurs.

**Table 2. Aboriginal site registered with Aboriginal Affairs**

Site identification	Access	Restriction	Site name	Site type
5145	open	none	Kojaneerup	Artefacts

**1.7 Social and economic impacts and benefits**

The implementation of this recovery plan has the potential to have some social and economic impact, where occurrences are used for recreational purposes. Recovery actions refer to continued liaison between stakeholders with regard to these areas.

**1.8 Affected interests**

Occurrences occur within the Shire of Gnowangerup on Parks and Wildlife managed land (Stirling Range National Park).

**1.9 Term of plan**

The plan will operate from 2016 to 2021 but will remain in force until withdrawn or replaced. It is intended that after five years, the need for further recovery actions and the need for an updated recovery plan will be evaluated.

**1.10 Strategies for recovery**

To identify, and influence the management of the areas in which the community occurs, so maintaining natural biological and non-biological attributes of the sites and the current area covered by the community.

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

## 2. THREATENING PROCESSES

**Phytophthora dieback.**

The most significant threat to the TEC is *Phytophthora dieback* resulting from the plant pathogen *Phytophthora cinnamomi* (Wills 1993; Barrett 1996; 2000; Barrett et al. 2008). The pathogen has spread to many of the peaks through the transport of infested soil. This has occurred largely through foot access since 1974, when *P. cinnamomi* was first noted in the Stirling Range National Park by CSIRO researchers (Grant and Barrett 2003). Infestations high in the landscape have led to considerable down-slope spread in broad fronts with extensive infestation of the thicket. The pathogen thrives in the humid montane conditions, susceptible vegetation and conducive soils. The entire extent of the eastern Stirling Range has been infested by *P. cinnamomi* to at least some degree, but small pockets of the TEC remain dieback-free or less extensively infested. These specific areas

(priority areas) on Pyungoorup, Bakers Knob, Isongerup, west Moongoongoonderup, East Bluff, Bluff Knoll, Coyanerup and Mt Success, where the community persists relatively intact, were mapped following ground based survey in the early 2000s.

Many characteristic species in the TEC are either susceptible or highly susceptible to the pathogen (Barrett et al. 2008; Shearer et al. 2013). These include *Banksia solandri*, *Banksia montana*, *Banksia concinna*, *Banksia oreophila*, *Lambertia uniflora*, *Andersonia axilliflora*, *Andersonia echinocephala*, *Leucopogon gnaphalioides*, *Latrobea colophona*, *Isopogon latifolius*; *Darwinia collina*, *Persoonia micranthera* and *Gastrolobium leakeanum*. For many of these species, samples taken from stressed plants in the ecosystem have returned positive (Barrett 1996).

Changes are most evident in the decline of species of Proteaceae that were dominant in the thicket (Keith et al. 2014). Photography from the 1960s to the 1980s records healthy stands of *B. montana*, *B. brownii* and *Isopogon latifolius* on the summit of Bluff Knoll. Monitoring since 1994 has shown these species to be locally extinct, or as in the case of *B. montana*, extremely rare.

Long term monitoring of *P. cinnamomi* susceptible defining species of the 'Montane heath and thicket' in the last two decades has shown a 35% decline in the number of populations of these species (Barrett & Yates 2014). The severity of this decline is further emphasized where long term monitoring of plants in individual populations has been undertaken showing a mean decline of 83% in the number of plants within populations. Population extinctions have been recorded for eight species from the TEC (Barrett & Yates 2014).

Aerial spraying of the fungicide phosphite to increase resistance of susceptible species to infection by *P. cinnamomi* began in 1997. Some 52 ha are sprayed annually to biennially at 12-24 kg/ha in eight targets (Appendix 1). The effectiveness of disease control has shown some variability between and within sites and with season. The reasons for this variability are not well understood and there has only been limited sampling of *in-planta* phosphite levels due to costs and access to analysis. There has been only limited use of controls to compare survival of susceptible species in sprayed and non-sprayed habitat (Barrett 2003). The abundance and diversity of susceptible species remains higher within long-term sprayed targets compared with non-sprayed areas although this has not been well quantified. Overall, the decline of susceptible obligate seeding species has been slowed by phosphite application (Keith et al. 2014) and this has 'bought time' for other conservation measures including *ex-situ* conservation.

### **Inappropriate fire regimes**

Inappropriate fire regimes are another major threat to the community. Most of the component species are killed by fire relying on seeds to regenerate. As a consequence, fire intervals are particularly important for the dynamics and persistence of the community. Major fires occurred in the thicket in February 1972, April 1991 and most recently in November 2000. Some patches were burnt by one, two or all three of the fires with a trend to more extensive and intensive fires over time (Barrett & Yates 2014).

In the 'Montane heath and thicket' TEC 71% of species are non-resprouters and of these 22% are serotinous (Barrett et al. 2009) rendering the community highly vulnerable to fire interval-dependant effects. For non-resprouting species, minimum fire intervals may be defined by a reproductive threshold at which the 50% of the population has reached reproductive maturity (Burrows et al. 2008; Gosper et al. 2013). For the 'Montane heath and thicket', the minimum time to at least 50% reproduction varies between 5 and 13 years for common and threatened non-resprouting species (Barrett & Yates 2014).

Approximately 5% of the ecosystem has remained unburnt since at least 1972, 2% was last burnt in 1991, 74% was burnt in both 2000 and 1991, and 19% was burnt in 2000 but not 1991. As a consequence, a large

proportion (74%) of the ecosystem has experienced a fire interval (9 years) at the lower bounds of risk for species persistence (Yates & Barrett 2014).

The TEC is still in the early stages of recovery and is therefore highly susceptible to fire returning in the near future. Measurements of growth for a dominant overstorey species, *Kunzea montana*, indicate that it may take at least 30 years for the community to recover maximum height structure following fire (Keith *et al.* 2014).

Fire may also interact with *P. cinnamomi* to increase disease impact and accelerate the collapse of obligate seeding populations of Proteaceae (Moore *et al.* 2015). The species most susceptible to fire-related decline (serotinous non-sprouting species in Proteaceae) are coincidentally the species most susceptible to the pathogen (Barrett & Yates 2014). Estimates of the density of this group of species in the four fire histories where the pathogen is present show they are most abundant in areas that have not been burnt since at least 1972 and lowest in areas that have experienced the most fire (Barrett & Yates 2014). Minimal recruitment of serotinous Proteaceae occurred in areas burnt in 1991 and 2000.

Recruitment of proteaceous species was particularly poor after the 2000 fire, even in areas that had not burnt in 1991. It is unclear whether this was due to season of the fire (spring), herbivory or disease impact as individuals of plants such as *Banksia montana* held adequate seed banks at the time of the fire.

### **Grazing / Browsing**

Montane ecosystems are vulnerable to the removal of vegetation cover through grazing or browsing by feral or native vertebrate fauna (Leigh *et al.* 1987; Bridle & Kirkpatrick 1999; Bridle *et al.* 2001). Since the original IRP for this TEC was completed in 1999 and specifically after the 2000 fire, the impact of browsing by vertebrate fauna has become increasingly apparent. Significant investment has been made in conservation actions for the 'Montane heath and thicket' TEC. These included threat mitigation e.g. application of the fungicide phosphite to mitigate *Phytophthora* dieback or *ex-situ* conservation strategies i.e. germplasm storage and translocations. It is critical that extant populations of key target species reach maturity and produce flowers and viable seed. Consequently, integrated management that addresses threats of browsing in combination with management of dieback and fire is vital in this ecosystem (Rathbone *et al.* 2016a).

Survey since 1994 had confirmed the presence of the herbivorous feral rabbit (*Oryctolagus cuniculus*) and native quokka (*Setonix brachyurus*) within the TEC (Barrett 1996). Rabbit control using 1080 oats was trialed in 2001 on Bluff Knoll, East Bluff and Pyungoorup (Blechynden 2001). Hand-laying of 1080 oats was implemented annually to tri-annually, depending on resources, from 2008 to 2015 (Pyungoorup baited only twice for logistical reasons). From 2001, plant cages were used to protect selected threatened flora (*B. montana*, *P. micranthera*, *A. axilliflora*, *L. gnaphalioides*, *D. collina*, *L. colophona*). This was associated with a significant recovery (Rathbone & Spencer. 2011).

Between 2011-2015, motion sensing cameras (Reconyx PC900) were used intermittently to identify vertebrate herbivores responsible for browsing of native vegetation, targeting areas with high browsing impacts and where threatened flora was present (Rathbone *et al.* 2016a). A total of 304 camera days of footage captured 96 events triggered by seven mammalian fauna. Quokka was the only strictly herbivorous native species recorded and was responsible for 75% of the events. Quokka was also captured directly browsing on three threatened species (*Andersonia axilliflora*, *Latrobea colophona* and *Leucopogon gnaphalioides*). All other native species observed were carnivorous, omnivorous or nectivorous: mardo (*Antechinus flavipes*), bush rat (*Rattus fuscipes*), quenda (*Isoodon obesulus*) and honey possum (*Tarsipes rostratus*). Two feral species were infrequently observed (the herbivorous rabbit (*Oryctolagus cuniculus*) and the carnivorous feral cat (*Felis catus*)).

Dietary analysis in 2015, through faecal examination of quokka and rabbit scats, revealed contrasting diets and implicates native rather than feral species as responsible for impacts on dicotyledonous species, and in particular those of conservation significance, including the threatened *Darwinia collina* (Rathbone *et al.* 2016a). In contrast, rabbit diet was largely comprised of monocot species.

Ten fenced exclosures (approximately 25 x 25m) were constructed between 2014-2015 (Rathbone *et al.* 2016a). The exclosures were located in sites that were completely or partially burnt by wildfire in 2000 and were chosen to protect focal areas of the TEC that contained high densities of threatened flora. Exclosure experiments conducted over 1-2 years revealed significant changes in abundance, cover and height of perennial herbs and importantly, an increase in growth and reproduction of four threatened endemic plants.

Detrimental impacts caused by native browsing fauna are not unprecedented and suggest disequilibrium in normal ecosystem process, potentially due to multiple interacting threats. Montane ecosystems may be particularly vulnerable to browsing due to their naturally slow recovery after disturbance.

In addition, browsing by quokka, as well as grazing by rabbit, reduces cover and increases soil exposure thereby creating environmental conditions more conducive to plant disease. For plant species with critically low population numbers, the impact of browsing poses a threat to population persistence and undermines investment in other conservation recovery actions (Rathbone *et al.* 2016a).

#### **Disturbance from recreational activities**

The higher peaks of the eastern Stirling Range attract visitors interested in bushwalking, nature observation and rock-climbing. Bluff Knoll is the most popular site visited, being the highest mountain in the southwest. The Ridge Walk from Ellen Peak to Bluff Knoll is a popular walk that is well known by bushwalkers throughout Australia. It takes between two and three days to complete, and preferred camping places include the Arrows and Bakers Knob. The walk is described in bushwalking guides by Morphett (1996) and Rankin (1989).

The Ridge Walk has implications for areas of the TEC that contain a relatively intact community as it traverses several of these remnants. Negative impacts that result from recreational activity include braiding of tracks, erosion, bare-ground occurrences, camp-fire remains, litter and nutrient enrichment of soils and introduction or spread of different isolates of *P. cinnamomi*.

Braiding of paths along the Ridge Walk has occurred in a number of places within the TEC, particularly on Bluff Knoll and East Bluff. Sections of the Ridge Walk have been marked, realigned and brushed to minimise any impacts on priority areas of the community. Side paths have formed on the summit of Bluff Knoll where people have explored or accessed viewing points. The paths in the montane community are particularly at risk of track erosion where they run across the contour lines, due to erodible soils and steep inclines.

There are scattered bare ground occurrences and fire places along the ridge walk. These impacts tend to be concentrated in saddle areas adjacent to the TEC but impacts also occur within the TEC on ridge-lines and summit areas.

Litter levels generally correlate with the level of visitor use and are greatest on Bluff Knoll. Although biodegradable, toilet paper on the mountains, and particularly on Bluff Knoll, has a significant visual impact. High visitor numbers may also result in increases in soil fertility and weed invasion associated with accumulation of human excreta on the peaks. In South Australia, herbs (weeds in particular), and sedges were favoured by even minor increases in soil fertility in soils that were originally nutrient poor (Specht 1963). The impact of increases in

soil fertility on composition of the TEC has not been monitored to date, it is considered that impacts are likely to be localised at present.

The major implication of past recreational activity for the Eastern Stirling Range Montane Heath and Thicket Community has been the spread of *P. cinnamomi* (Gillen & Watson 1993; Wills 1993). It is apparent that the pathogen has spread to many of the peaks through the transport of infected soil, mostly by foot access, as a result of both recreational and other activities. There is also the potential for spread of the pathogen by fauna movement.

The current implications of recreational soil vectoring are the spread of the pathogen to small disease-free pockets or the introduction of new isolates of *P. cinnamomi* (Bryan Shearer pers. comm.). Path drainage is important in relation to both erosion and the risk of spreading dieback (Watson & Passmore 1993). In wet conditions pooling of water occurs near the summit areas of Bluff Knoll. These wet areas provide ideal sites for the transfer of *Phytophthora* through soil collected on walking boots (Gillen & Watson 1993). Moist soil conditions prevail for much of the year on the higher peaks, particularly near mountain summits associated with run-off from rock faces.

### **Climate change**

Climate change as a threatening process is outside the scope of this interim recovery plan and the temperature and the rainfall thresholds for individual species persistence are unknown. There has been only limited collection of climatic data for the TEC. However, as this community occupies mountain tops there is literally nowhere for many vulnerable species to migrate to.

The consensus among global climate models is that temperature will increase and rainfall will continue to decline in south west WA with associated increase in wildfire risk. The potential for fire intervals below the tolerance threshold for this community is likely to increase (Barrett & Yates 2014).

Projected increases in temperature may also negatively affect the persistence of component species. Investigations of temperature and seed germination for selected species from the 'Montane heath and thicket' show a negative relationship between increasing mean temperature and germination for some species (Cochrane *et al.* 2011).

## **3. GUIDE FOR DECISION-MAKERS**

Any on-ground works (significant clearing, burns, proposals with potential to alter drainage or water quality) within or in the vicinity of TEC will require environmental impact assessment. Proponents should demonstrate that on-ground works will not have a significant impact on the TEC. These include:

- proposals that will result in a significant increase in fire frequency;
- proposals that will exacerbate known threatening processes including *Phytophthora* dieback and browsing;
- proposals that cause a significant increase in opportunity for physical damage through trampling of vegetation.

## 4. CONSERVATION STATUS

The TEC was endorsed by the WA Minister for Environment in 2001 as Critically Endangered and was listed as an Endangered threatened ecological community (TEC) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in July 2000.

## 5. RECOVERY OBJECTIVES AND CRITERIA

### 5.1. Objectives

To conserve the ecological and conservation values of the 'Montane heath and thicket' TEC by:

- Maintaining or improving the overall condition of the community.
- Reducing the level of threat to the community.

### 5.2. Criteria for success:

- 80% or more of the area of priority areas covered by this interim recovery plan are maintained in the same condition rank or improved through actions implemented over the life of the plan, excluding effects of drying climate that are outside the scope of this plan.

### 5.3. Criteria for failure:

- Decline to a lower condition rank of 20% or more of the area of priority areas covered by this interim recovery plan through inaction or inappropriate actions, excluding effects of drying climate that are outside the scope of this plan.

## 6. RECOVERY ACTIONS

The responsible authority is frequently listed as the relevant Parks and Wildlife District. This refers largely to initiating and guiding actions. However, in general the relevant Parks and Wildlife District, in liaison with the Species and Communities Branch and the relevant Recovery Team share the primary responsibility for securing funds for, and/or coordinating the implementation of, recovery actions.

### 6.1. Existing recovery actions

Significant recovery actions have been completed for the community:

- The extent and boundaries of all known occurrences have been mapped.
- Dieback-free areas and areas where the community persists relatively intact (priority areas) were mapped following ground based survey in the early 2000s.
- Threats for areas currently dieback-free or relatively intact have been evaluated.
- Areas of the community have been ranked in terms of relative urgency for recovery actions and key recovery actions identified.
- Threatening processes have been managed for the identified priority areas:
  - Aerial phosphite spraying was initiated in 1997, since then the following eight targets have been sprayed regularly on an annual to biennial basis; Bluff Knoll (16ha), East Bluff (3ha), Isongerup (13ha),



Pyungoorup (3ha), Bakers Knob (2ha), Moongoongoonderup (5ha) Coyanerup (1ha) (from 2005), Mt Success (9ha) (Appendix 1). Prior to the 2000 fire, sites were sprayed at 24 kg/ha biennially. After the 2000 fire, spraying resumed in 2002 at a lower rate of 6-12 kg/ha, with annual to biennial spraying of 52ha at 12 kg/ha since 2008.

- Flora monitoring has been undertaken to monitor the survival of susceptible (mainly threatened) species and to evaluate the effectiveness of phosphite application (Barrett 2003, Keith *et al.* 2014; Barrett & Yates 2014).
- A long-term research program investigating the fire ecology of the eastern Stirling Range 'Montane heath and thicket' Community was initiated in 2001 and a paper and book chapter published (Barrett and Yates 2014; Keith *et al.* 2014).
- Research into dieback-fire interactions has been undertaken within the adjacent 'Montane mallee thicket' PEC and a paper published (Moore *et al.* 2014)
- A paper on extinction risks for several plant species within the TEC threatened by *Phytophthora cinnamomi* was presented at the 2007 MedEcos Conference and published in 2008 (Barrett *et al.* 2008).
- A fire management strategy (Barrett *et al.* 2010) has been developed for the Stirling Range National Park and the TEC identified as a fire exclusion zone until the community has recovered sufficiently from the 2000 wildfire.
- A rabbit control strategy has been implemented since 2008 with baiting annually to triannually mainly on Bluff Knoll and East Bluff, with Pyungoorup baited twice.
- Multiple seed collections have been made from threatened, priority and keystone species from the TEC and are currently being stored in the department's Threatened Flora Seed Centre at -18°C.
- Material for tissue culture has been collected and techniques for propagation are being developed (e.g. for *Banksia montana*) by Botanic Gardens and Parks Authority (BGPA).
- Remote sensing cameras were used 2011-2015 to determine the source of grazing impacts for individual species; rabbit and quokka scats were analysed in 2015 to determine what plant material was present.
- Remote sensing cameras were used in 2015 to assess pollinators for the endemic species *Banksia montana*.
- Individual Threatened flora (*B. montana*, *P. micranthera*, *L. gnaphalioides*, *L. colophona*, *D. collina*, *A. axilliflora*) plants within the TEC were fenced from 2001 to reduce grazing impacts (Rathbone & Spencer 2011). Larger fenced enclosures to protect the TEC were constructed on Bluff Knoll, Coyanerup and East Bluff in 2014-2015 and detailed monitoring established (Rathbone *et al.* 2016a).
- A trial of small-scale restoration planting of *Banksia oreophila* seedlings, a keystone species, was implemented in 2010 (Rathbone and Spencer 2011) and 2013 with 129 seedlings planted in nine small enclosures. In 2015 there was 66% survival of the 2010 plantings with 12 plants reproductive, survival of 2013 plantings was lower (25%).
- Direct seeding of *B. oreophila* was trialled in the larger fenced enclosures in 2015.
- A Landscape article (Rathbone *et al.* 2016b) and an article in the Australian Plant Conservation Bulletin (Barrett & Rathbone 2016) describes recovery actions for the Montane heath and thicket TEC including fencing and monitoring activities. Information on the recovery of the TEC has been presented at several seminars and symposiums.
- Landscape and other articles have promoted the values of the TEC and its species (e.g. Cochrane and Barrett 2000; Cochrane and Barrett 2006; Cochrane *et al.* 2009).
- Ex-situ conservation of key species from the TEC has been documented (Cochrane and Barrett 2009; Cochrane *et al.* 2010 ; Barrett *et al.* 2011).
- A paper on the germination ecology of selected species from the Montane heath and thicket TEC showed a negative relationship between increasing temperature and germination (Cochrane *et al.* 2011).
- Invertebrates and assemblages associated with key TEC species have been surveyed (Moir *et al.* 2009, 2012, 2016; Moir & Vesk 2012).
- The alignment, condition and use of the ridge walk and risks posed to priority areas of the community have been investigated.

- Visitor usage of the Ridge Walk and its impact on the community has been monitored.
- Sections of the Ridge Walk have been marked, realigned and brushed to minimise any impacts on priority areas of the community.
- Signage was erected along Bluff Knoll track to highlight the values of the community and reduce trampling. Additional signage was deployed in 2014 to explain threats to the community and the reason for fencing.
- Information has been provided to Ridge Walk users on values and hygiene practices and trailhead signs established. The 'Code of Conduct for backcountry use in the Stirling Range National Park' has been reviewed.
- All relevant land managers have been notified of the importance of the community.
- A recovery team for the community was initiated and ran until 2008 when the Albany Threatened Flora Recovery Team assumed responsibility for co-ordination of recovery actions.

## 6.2 Recommended recovery actions

### 1. Coordinate recovery actions

The ADTFRT will oversee the implementation of the recovery actions for the TEC and will include information on progress in their annual report to the department's Corporate Executive and funding bodies.

<b>Responsibility:</b>	Department of Parks and Wildlife (Albany District), with assistance from the ADTFRT
<b>Cost:</b>	<b>\$2,000 per year</b>
<b>Completion date:</b>	<b>Ongoing</b>

### 2. Apply phosphite to priority areas

Phosphite will continue to be applied at 12-24 kg/ha annually to biennially to priority areas (Bluff Knoll, Coyanerup, East Bluff, Moongoongoonderup, Isongerup, Bakers Knob, Pyungoorup and Mt Success summit ridge).

Where possible novel phosphite sampling techniques will be used to monitor in-plant phosphite levels and spray regime adjusted to suit.

<b>Responsibility:</b>	Department of Parks and Wildlife (South Coast Region, Albany District)
<b>Cost:</b>	<b>\$18,000 per year</b>
<b>Completion date:</b>	Ongoing

### 3. Implement a browsing management strategy

Existing grazing enclosures on Bluff Knoll, East Bluff and Coyanerup will be maintained, and new enclosures established where funds permit.

<b>Responsibility:</b>	Department of Parks and Wildlife (South Coast Region, Albany District)
<b>Cost:</b>	<b>\$6,000 per year</b>
<b>Completion date:</b>	Ongoing

### 4. Implement a rabbit control program

Scattered baiting 2-3 times over summer will be undertaken with 1080 oats at areas with high concentrations of rabbits including Bluff Knoll, East Bluff and Pyungoorup.

<b>Responsibility:</b>	Department of Parks and Wildlife (South Coast Region, Albany District)
<b>Cost:</b>	<b>\$4,000 per year</b>
<b>Completion date:</b>	Ongoing

**5. Implement a flora and vegetation monitoring program to evaluate the effectiveness of disease and herbivore management.**

Annual and biennial monitoring of growth and reproduction of target threatened flora within and without exclosures and monitoring of recovery of plant community in nested quadrats within exclosures. Monitor survival of key threatened flora including population stability (expansion or decline), pollinator activity, growth, reproduction and seed production, recruitment and longevity. Compare abundance and number of susceptible species within long term sprayed targets areas with non-sprayed areas of the TEC. Install an automated weather station to document rainfall and temperature trends for analysis in relation to vegetation health trends.

<b>Responsibility:</b>	Department of Parks and Wildlife (Albany)
<b>Cost:</b>	<b>\$15,000 in 1<sup>st</sup> year, \$10,000 per year in 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> years</b>
<b>Completion date:</b>	Ongoing

**6. Maintain disease hygiene**

Dieback hygiene (outlined in Department of Parks and Wildlife 2014) will be followed with access restricted to dry soil conditions where possible, or additional hygiene measures used during moist soil conditions when working away from trails and routes open to the public.

<b>Responsibility:</b>	Department of Parks and Wildlife (Albany)
<b>Cost:</b>	<b>\$1,000 per year</b>
<b>Completion date:</b>	Ongoing

**7. Implement a fire management strategy**

As indicated in the Stirling Range National Park Fire Management Strategy (2010) all occurrences of the TECs are to be excluded from fire for the foreseeable future (Barrett *et al.* 2010). As part of the strategy lowland areas may be burnt to provide protection to the TEC.

<b>Responsibility:</b>	Department of Parks and Wildlife (Albany) in liaison with surrounding landholders
<b>Cost:</b>	<b>\$5,000 per year</b>
<b>Completion date:</b>	Ongoing

**8. Obtain additional ecological information**

Increased knowledge of the ecology of the community will provide a scientific basis for management of the TEC.

- Identify resistant genotypes for key susceptible species including proteaceous species for restoration purposes.
- Characterise microhabitats within the TEC in terms of disease expression considering aspect, soils and drainage and identify suitable areas for restoration.
- Collect climatic data (rainfall, soil and air, temperature, soil moisture and humidity) for the community.
- Determine the range of isolates of *P. cinnamomi* present within the TEC.
- Compare levels of inoculum of *P. cinnamomi* in phosphite sprayed versus non-sprayed habitat.

Other research may include:

1. Soil seed bank dynamics and the role of various factors including disturbance, competition, drought, inundation and grazing in recruitment and seedling survival.
2. Reproductive success and pollination biology of key species.
3. Investigation of minimum viable population size for key species including invertebrate species dependent on the TEC.

<b>Responsibility:</b>	Department of Parks and Wildlife (Albany) in liaison with surrounding landholders
<b>Cost:</b>	<b>\$20,000 per year</b>
<b>Completion date:</b>	Ongoing

## 9. Collect and store seed and germplasm

Preservation of genetic material is essential to guard against extinction of the species if the wild populations are lost. It is recommended that seed be collected from key components of the TEC including threatened, endemic as well as more widespread flora and stored in the TFSC.

Continue to develop tissue culture techniques for key species.

<b>Responsibility:</b>	Department of Parks and Wildlife (Albany District, TFSC)
<b>Cost:</b>	<b>\$10,000 per year</b>
<b>Completion date:</b>	Ongoing

## 10. Develop and implement a restoration strategy

Re-stock priority areas of the community within suitable habitat with keystone species, fencing all seedlings at risk of browsing.

Evaluate the use of direct seeding versus the use of seedlings or trial tissue-cultured plants.

<b>Responsibility:</b>	Department of Parks and Wildlife (Albany District)
<b>Cost:</b>	<b>\$20,000 per year</b>
<b>Completion date:</b>	Ongoing

## 11. Protect community from physical damage from trampling

Monitor trail condition where it traverses priority areas of the TEC, use track markers, signage and rehabilitation where appropriate to protect the TEC from physical damage and litter.

<b>Responsibility:</b>	Department of Parks and Wildlife (Albany District)
<b>Cost:</b>	<b>\$3,000 per year</b>
<b>Completion date:</b>	Ongoing

## 12. Undertake liaison with land managers and Aboriginal communities

Staff from the department's Albany District will liaise with parks staff to ensure that the TEC is not accidentally damaged and that the habitat is maintained in a suitable condition for the conservation of component species. The TEC occurs within the Stirling Range National Park in an area that may be culturally sensitive. Consultation with the Aboriginal community will take place to determine if there are any issues or interests in areas that are habitat for the TEC.

<b>Responsibility:</b>	Department of Parks and Wildlife (Albany District)
<b>Cost:</b>	<b>\$4,000 per year</b>
<b>Completion:</b>	Ongoing

## 13. Promote awareness

The importance of biodiversity conservation and the protection of the TEC will be promoted to the public. This will be achieved through the dissemination of information using print and electronic media, seminars and poster displays. Formal links with local naturalist groups and interested individuals will also be encouraged.

<b>Responsibility:</b>	The department (Albany District, Species and Communities Branch (SCB) and Corporate Relations), with assistance from the ADTFRT
<b>Cost:</b>	<b>\$4,000 per year</b>
<b>Completion:</b>	<b>Year 3</b>

## 14. Map habitat critical to survival

Although habitat critical to survival is described in Section 1, the areas as described have not yet been mapped and that will be completed under this action.

<b>Responsibility:</b>	Department of Parks and Wildlife (Albany District, SCB)
<b>Cost:</b>	\$4,000 in the first and second years
<b>Completion date:</b>	Year 2

## 15. Report on recovery plan implementation

Reporting will be part of annual reports prepared by the Recovery Team for the Department of Parks and Wildlife, and will include results of analysis of monitoring within an adaptive management framework. A final report will be presented as part of the next review and update of the recovery plan, if deemed necessary.

<b>Responsibility:</b>	Department of Parks and Wildlife (South Coast Regions, Albany Districts SCB)
<b>Cost:</b>	<b>\$4,000 per year</b>
<b>Completion date:</b>	Ongoing

## 16. Review this plan and assess the need for further recovery actions

At the end of the five-year term of this plan, if the ecological community is still listed as threatened the need for further recovery actions, or a review of this plan will be assessed and a revised plan prepared if necessary.

**Responsibility:** Department of Parks and Wildlife (SCB, Albany District)

**Cost:** \$10,000 in year 5

**Completion date:** Year 5

## 7. TERM OF PLAN

The plan will operate from 2016 to 2021 but will remain in force until withdrawn or replaced. It is intended that after five years, if the ecological community is still listed as threatened, the need for further recovery actions and for an updated recovery plan will be evaluated.

## 8. REFERENCES

- Barrett S. (1996). Biological Survey of Mountains of southern Western Australia. Department of Conservation and Land Management, Albany.
- Barrett S. (2000). Eastern Stirling Range Montane Heath and Thicket Community Interim Recovery Plan No. 52, 1999–2002. Department of Conservation and Land Management, Albany, Western Australia.
- Barrett S. (2001). Phytotoxic effects of phosphite on native plant communities in southern Western Australia, Murdoch University, Perth.
- Barrett S., Dillon R., Cochrane A., Monks L. (2011). Conservation introduction of a threatened narrow range endemic species, *Banksia montana*, from the Stirling Range National Park, southern Western Australia. In Soorae, P. S. (ed) 2011 Global Re-introduction Perspectives: 2011. More case studies from around the globe. Gland, Switzerland: IUCN/SSC Re-introduction Specialist Group and Abu Dhabi, UAE: Environment Agency-Abu Dhabi. Pp. 210-235.
- Barrett S. (2003). Monitoring of aerial phosphite applications for the control of *Phytophthora cinnamomi* in the Albany District. in *Phytophthora in Forests and Natural Ecosystems*. 2nd International IUFRO Working Party 7.02.09 Meeting, Albany, W. Australia 30th Sept–5th Oct, 2001. Eds. JA McComb, GE StJ Hardy and IC Tommerup (Murdoch University Print) pp 132–137. Centre for Phytophthora Research and Management, Murdoch, Western Australia.
- Barrett S., Comer S., McQuoid N., Porter M., Tiller C., Utber D. (2009). Identification and conservation of fire sensitive ecosystems and species of the South Coast Natural Resource Management Region. Department of Environment and Conservation, Albany.
- Barrett S., Comer S., Freebury G., Grant M., Broomhall G., Hilder V. (2010). Fire Management Strategy for the Stirling Range National Park. Department of Environment and Conservation, Western Australia.
- Barrett S., Shearer B.L., Crane C. and Cochrane A. (2008). An extinction-risk assessment tool for flora threatened by *Phytophthora cinnamomi*. *Australian Journal of Botany* **56**, 477–486.
- Barrett S., Yates C.J. (2014). Risks to a mountain summit ecosystem with endemic biota in southwestern Australia. *Austral Ecology* **40**, 423-432.
- Barrett S., Rathbone D. (2016). Management of herbivory in the Montane Heath and Thicket TEC of the eastern Stirling Range, Western Australia. *Australian Plant Conservation Bulletin* **24**, 25-26.



- Blechynden P. (2001). Proposal for the control of rabbits in the Stirling Range National Park. Department of Conservation and Land Management, Albany.
- Bridle K.L., Kirkpatrick J.B. (1999). Comparative effects of stock and wild vertebrate herbivore grazing on treeless subalpine vegetation, Eastern Central Plateau, Tasmania. *Australian Journal of Botany* **47**, 817-834.
- Bridle K.L., Kirkpatrick J.B., Cullen P., Shepherd R.R. (2001). Recovery in alpine heath and grassland following burning and grazing, Eastern Central Plateau, Tasmania, Australia. *Arctic Antarctic and Alpine Research* **33**, 348-356.
- Burrows N.D., Wardell-Johnson G., Ward B. (2008). Post-fire juvenile period of plants in south-west Australia forests and implications for fire management. *J. Roy. Soc. West. Aust.* **91**, 163-74.
- Coates D.J., McArthur S., Byrne M. (2015). Significant genetic diversity loss following pathogen driven population extinction in the rare endemic *Banksia brownii* (Proteaceae). *Biological Conservation* **192**, 353-360.
- Cochrane A., Barrett S. (2000). Drummond's Grass. From presumed extinct to perched on mountain summits. *Landscape* **15** (4), 44-47.
- Cochrane A., Barrett S. (2006). Threatened communities on high: Stirling plants. *Landscape* **22** (2), 26-31.
- Cochrane A., Barrett S. (2009). The role of seed orchards in plant conservation. *Australasian Plant Conservation* **17** (4), 10-12.
- Cochrane A., Barrett S., Watson J. (2009). Responses to threats and impacts on the outstanding biodiversity values of low-altitude mountains in south Western Australia. *Mountain Forum Bulletin* **9**(2), 8-10.
- Cochrane J., Barrett S., Monks L., Dillon R. (2010). Partnering conservation actions. Inter-situ solutions to recover threatened species in South West Western Australia. *Kew Bulletin* **65**, 655-662.
- Cochrane A., Daws M.I., Hay F.R. (2011). Seed-based approach for identifying flora at risk from climate warming. *Austral Ecology* **36**, 923-35.
- Cochrane A., Barrett S. (2014). Celebrating 21 years insuring the Stirling Range Flora. *Landscape* **30**: 24-27.
- Courtney J. (1993). Climate. In: Mountains of Mystery: a Natural History of the Stirling Range (eds C. Thomson, G. Hall, G. Friend), pp. 5-11. Department of Conservation and Land Management, Como, WA.
- Department of Parks and Wildlife (2015a). Corporate Policy Statement No. 35 *Conserving Threatened Species and Ecological Communities*. Perth, Western Australia.
- Department of Parks and Wildlife (2015b). Corporate Guideline No. 35 *Listing and Recovery of Threatened Species and Ecological Communities*. Perth, Western Australia.
- Diels L. (2007). The plant life of Western Australia, South of the Tropics. *Conservation. Science W. Aust.* **6**, 1-373.
- Gillen K., Watson J.R. (1993). Controlling *Phytophthora cinnamomi* in the mountains of south Western Australia. *Australian Ranger*. **27**, 18-20.
- Gosper C.R., Prober S.M., Yates C.J. (2013). Estimating fire interval bounds using vital attributes: implications of uncertainty and among population variability. *Ecol. Appl.* **23**, 924-35.
- Grant M., Barrett S. (2003). The distribution and impact of *Phytophthora cinnamomi* Rands in the south coast region of Western Australia. In: *Phytophthora in Forests and Natural Ecosystems: 2nd International IUFRO Working Party 7.02.09 Meeting*, Albany, W. Australia, 30th Sept-5th Oct, 2001 (eds J. McComb, G. Hardy, I. Tommerup), 34-40. Centre for Phytophthora Research and Management, Murdoch.
- Gullan P.J., Moir M.L., Leng M.C. (2013). A new species of mealybug (Hemiptera: Pseudococcidae) from critically endangered *Banksia montana* in Western Australia. *Rec. West. Aust. Mus.* **28**, 013-20.
- Harvey M.S. (2002). Short-range endemism in the Australian fauna: some examples from non-marine environments. *Invert. Syst.* **16**, 555-70.
- Keith D., Lindenmayer D., Lowe A., Russell-Smith J., Barrett S., Enright N. *et al.* (2014). Heathlands. In: *Biodiversity and Environmental Change: Monitoring, Challenges and Direction* (eds D. Lindenmayer, E. Burns, N. Thurgate and A. Lowe) pp. 213-281. CSIRO Publishing, Australia.
- Leigh J., Wimbush D., Wood D., Holgate M., Slee A., Stanger M., Forrester R (1987). Effects of rabbit grazing and fire on a sub-alpine environment. I. herbaceous and shrubby vegetation. *Australian Journal of Botany* **35**, 433-464.

- Moir M.L., Brennan K.E.C., Harvey M.S. (2009). Diversity, endemism and species turnover of millipedes within the south-western Australian global biodiversity hotspot. *J. of Biog.* **36**, 1958-71.
- Moir M.L., Vesk P.A., Brennan K.E.C., Keith D.A., Hughes L., McCarthy M.A. (2010). Current constraints and future directions in estimating coextinction. *Conservation Biology* **24**, 682-690.
- Moir M.L., Vesk P.A., Brennan K.E.C., Keith D.A., McCarthy M.A., Hughes L. (2011). Identifying and managing cothreatened invertebrates through assessment of coextinction risk. *Conservation Biology* **25**, 787-796.
- Moir M.L., Vesk P.A. (2012). Should we try to save parasites too? Extinction of dependent species during translocation of threatened hosts. *Decision Point* **61**:7-8.
- Moir M.L., Vesk, P.A., Brennan K.E.C., Poulin R., Hughes, L., Keith D.A., McCarthy M.A., Coates D.J. (2012). Considering extinction of dependent species during translocation, *ex situ* conservation and assisted migration of threatened hosts. *Conservation Biology* **26**, 199–207.
- Moir M.L., Coates D.J., Kensington W.J., Barrett S., Taylor G.S. (2016). Concordance in evolutionary history of threatened plant and insect populations warrant unified conservation management approaches. *Biological Conservation* **198**: 135–144.
- Moore N., Barrett S., Howard K., Craig M.D., Bowen B., Shearer B., Hardy G. (2015). Time since fire and average fire interval are the best predictors of *Phytophthora cinnamomi* activity in heathlands of south-western Australia. *Australian Journal of Botany*, **62**, 587-593.
- Morphett A.T. (1996). Mountain walks in the Stirling Range - a pictorial guide. Part 2 The peaks to the east of Chester Pass. Torridon Publications, Capel.
- Muir B.G. (1977). Biological Survey of the Western Australian Wheatbelt: part 2. Vegetation and Habitat of Bending Reserve. *Rec. West. Aus. Mus. Suppl. No. 3*.
- Pignatti E., Pignatti S., Lucchese F. (1993). Plant Communities of the Stirling Range, Western Australia. *J. Veg. Sci.* **4**: 477-488
- Rankin R. (1989) Classic wild walks of Australia. Rankin, Brisbane.
- Rathbone D., Spencer M. (2011). Management of *Phytophthora* and Rabbit Impacts on Threatened Ecological Communities in the Stirling Range and Mount Lindesay Areas. Final Report to South Coast National Resource Management. Department of Environment and Conservation, Albany Work Centre, Albany.
- Rathbone D., Barrett S., Lehmann D., Harper E. (2016a). Vertebrate browsing impacts in a threatened montane plant community. Unpublished report to Department of Parks and Wildlife, Albany District, Western Australia.
- Rathbone D., Barrett S., Lehmann D., Harper E. (2016b). Battling the Odds. *Landscape* **31**(3), pp. 40–44.
- Rix MG, Harvey MS (2012) Phylogeny and historical biogeography of ancient assassin spiders (Aranae: Archaeidae) in the Australian mesic zone: Evidence for Miocene speciation with Tertiary refugia. *Mol. Phylogenet. Evol.* **62**, 375-96.
- Semeniuk V. (1993). Geology, landforms, soils and hydrology. In: Mountains of Mystery: a Natural History of the Stirling Range (eds C. Thomson, G. Hall, G. Friend), 13-26. Department of Conservation and Land Management, Como, WA.
- Shearer B.L., Crane C.E., Cochrane J.A. (2013). Variation in susceptibility of *Banksia* (including *Dryandra*) to *Phytophthora cinnamomi*. *Australasian Plant Path.* **42**, 351–361
- Specht, R.L. (1963). Dark Island Heath (Ninety-Mile Plain, South Australia) VIII. The effect of fertilisers on composition and growth, 1950-60. *Australian Journal of Botany.* **11**, 67-94.
- Taylor G.S., Moir M.L. (2014). Further evidence of the coextinction threat for jumping plant-lice: three new *Acizzia* (Psyllidae) and *Trioza* (Trioziidae) from Western Australia. *Insect Syst. Evol.* DOI 10.1163/1876312X-00002107
- Watson J.R., Passmore T.P. (1993). A Western Australian approach to path restoration. *Australian Ranger.* **27**: 31-34
- Wills, R. (1993). The ecological impact of *Phytophthora cinnamomi* in the Stirling Range National Park, Western Australia. *Australian Journal of Ecology* **18**, 145–159.

### **Existing approved interim recovery plans/management prescriptions relevant to the Montane Heath and Thicket TEC**

- Barrett S., Comer S., Freebury G., Grant M., Broomhall G. and Hilder V. (2010). Fire Management Strategy for the Stirling Range National Park. Department of Environment and Conservation, Western Australia.
- Dept. of Conservation and land management (1999). Stirling Range and Porongurup National Parks Management Plan 1999-2009.
- Evans R., Barrett S., Stack G., Brown A. (2008). Giant Andersonia (*Andersonia axilliflora*) Interim Recovery Plan No 147 2003-2008.
- Gilfillan S., Barrett S. (2005) Feather-leaved banksia (*Banksia brownii*) Interim Recovery Plan No 210 2005-2010.
- Gilfillan S, Barrett S, Hartley R, Yates C (2005). Stirling Range dryandra (*Banksia montana*) Interim Recovery Plan No 207 2005-2010.
- Hartley R., Barrett S. (2005). Yellow mountain bell (*Darwinia collina*) Interim Recovery Plan No 201 2005-2010.
- Hartley R., Barrett S. (2005). Fairall's lambertia (*Lambertia fairallii*) Interim Recovery Plan No 205 2005-2010.
- Holland E., Evans R., Brown A. (1999). Mountain paper heath (*Sphenotoma drummondii*) Interim Recovery Plan No 301 Summary of Recovery Actions 1999-2002.
- Lu R., Barrett S., Brown A. (2013). Stirling Range beard heath (*Leucopogon gnaphalioides*) Interim Recovery Plan No 334 2013-2018.
- Lu R., Brown A. (2010). *Latrobea colophona* Interim Recovery Plan No 301 2010-2015.
- Stack G., Brown A. (2003). Small-flowered snottygobble (*Personia micranthera*) Interim Recovery Plan No 145 2003-2008.

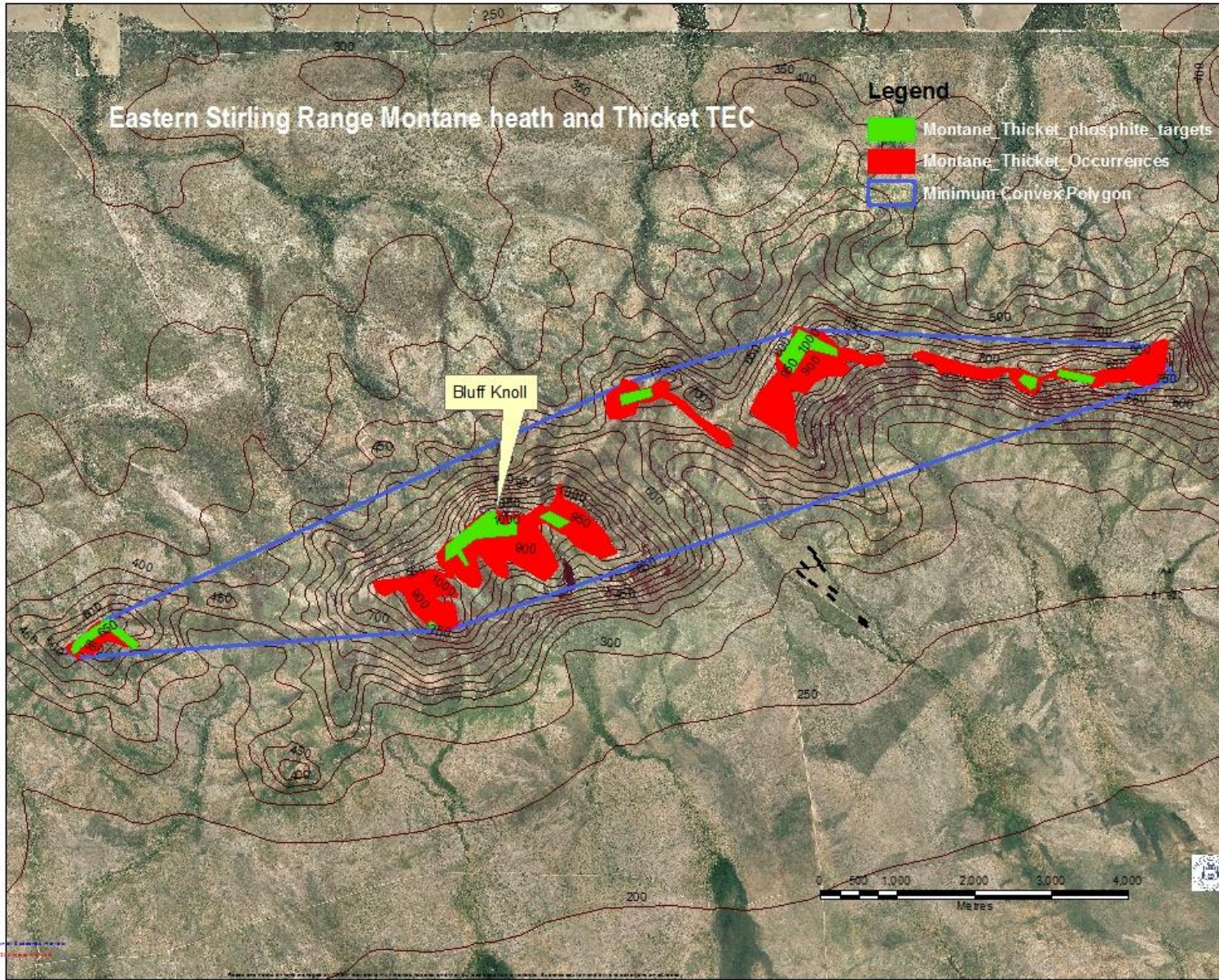
## Summary of costs for recovery actions

Recovery Action	Year 1	Year 2	Year 3	Year 4	Year 5
Coordinate recovery actions	2000	2000	2000	2000	2000
Apply phosphite to priority areas	18000	18000	18000	18000	18000
Implement a browsing management strategy	6000	6000	6000	6000	6000
Implement a rabbit control program	4000	4000	4000	4000	4000
Implement a flora and vegetation monitoring program to evaluate the effectiveness of disease and herbivore management.	15000	10000	10000	10000	10000
Maintain disease hygiene	1000	1000	1000	1000	1000
Implement a fire management strategy	5000	5000	5000	5000	5000
Obtain additional ecological information	20000	20000	20000	20000	20000
Collect and store seed and germplasm	10000	10000	10000	10000	10000
Develop and implement a restoration strategy	20000	20000	20000	20000	20000
Protect community from physical damage from trampling	3000	3000	3000	3000	3000
Undertake liaison with land managers and Aboriginal communities	4000	4000	4000	4000	4000
Promote awareness	4000	4000	4000	4000	4000
Map habitat critical to survival	4000	4000			
Report on recovery plan implementation	4000	4000	4000	4000	4000
Review this plan and assess the need for further recovery actions					10000
<b>Total \$573,000</b>	<b>120,000</b>	<b>115,000</b>	<b>111,000</b>	<b>111,000</b>	<b>121,000</b>

Total costs over five years: \$578,000



# Appendix 1





## Appendix 2

### Taxa that commonly occur in the Montane Heath and Thicket TEC

#### **Anarthriaceae**

*Anarthria prolifera*

#### **Cyperaceae**

*Tetraria* sp. Jarrah Forest (R. Davis 7391)

*Lepidosperma* sp. Bluff Knoll robust (GJK 12595)

*Schoenus efoliatus*

#### **Dasypogonaceae**

*Kingia australis*

#### **Hemerocallidaceae**

*Stypandra glauca*

#### **Poaceae**

*Amphipogon laguroides* subsp. *laguriodes*

*Deyeuxia drummondii*

*Rhytidosperma caespitosa*

#### **Restionaceae**

*Desmocladius flexuosus*

#### **Orchidaceae**

*Cryptostylis ovata*

*Thelymitra graminea*

#### **Apiaceae**

*Actinotus rhomboideus*

*Xanthosia rotundifolia* var. *rotundifolia*

*Platysace* sp. Stirling (J.M. Fox 88/262)

#### **Asteraceae**

*Xerochrysum bracteatum*

#### **Droseraceae**

*Drosera huegelii*

*Drosera stolonifera* subsp. *monticola*

#### **Ericaceae**

*Andersonia axilliflora*

*Andersonia echinocephala*

*Lysinema fimbriatum*

*Dielsiodoxa tamariscina*

*Leucopogon gnaphalioides*

*Leucopogon interstans*

*Leucopogon atherolepis*

*Sphenotoma drummondii*

*Sphenotoma* sp. Stirling Range (P.G. Wilson 4235)

#### **Euphorbiaceae**

*Amperea conferta*

#### **Fabaceae**

*Aotus genistoides*

*Gastrolobium leakeanum*

*Gompholobium* aff. *villosum*

*Latrobea colophona*

#### **Goodeniaceae**

*Dampiera leptoclada*

*Veillea foliosa*

#### **Mimosaceae**

*Acacia drummondii* subsp. *elegans*

#### **Myrtaceae**

*Astartea montana*

*Beaufortia decussata*

*Beaufortia anisandra*

*Calothamnus montanus*

*Darwinia collina*

*Darwinia squarrosa*

*Darwinia nubigena*

*Melaleuca thymoides*

*Hypocalymma myrtifolium*

*Kunzea montana*

*Taxandria floribunda*

*Taxandria parviceps*

#### **Proteaceae**

*Adenanthos filifolius*

*Banksia solandri*

*Banksia brownii*

*Banksia oreophila*

*Banksia montana*

*Banksia concinna*

*Banksia formosa*

*Banksia grandis*

*Hakea florida*

*Persoonia micranthera*

*Isopogon latifolius*

*Lambertia uniflora*

#### **Lamiaceae**

*Microcorys* sp. Stirling Range (S Barrett 1392)

#### **Lauraceae**

*Cassytha glabella*

#### **Pittosporaceae**

*Billardiera drummondii*

#### **Rubiaceae**

*Opercularia* sp. Stirling Range (M. Hislop 2839)

#### **Rutaceae**

*Boronia crenulata* var. *viminea*

*Boronia spathulata*

*Muiriantha hassellii*

#### **Santalaceae**

*Leptomeria squarrulosa*

#### **Stylidiaceae**

*Levenhookia pusilla*

*Stylidium bellum*

*Stylidium ?diversifolium*

*Stylidium keigheryi*

*Stylidium rosulatum*

*Stylidium* sp. Bluff Knoll (S. Barrett s.n. 8/11/1994)

*Stylidium scandens*

#### **Thymeliaceae**

*Pimelea angustifolia*