National Recovery Plan for Grampians Pincushion-lily *Borya mirabilis*

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This is a Recovery Plan prepared under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, with the assistance of funding provided by the Australian Government.

This Recovery Plan has been developed with the involvement and cooperation of a range of stakeholders, but individual stakeholders have not necessarily committed to undertaking specific actions. The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved. Proposed actions may be subject to modification over the life of the plan due to changes in knowledge.

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Summary

The Grampians Pincushion-lily (*Borya mirabilis*) is a small tufted plant of the family Liliaceae endemic to western Victoria, in the Grampians National Park, where it grows in low open shrubland on sandstone outcrops. Only two populations are known: a single remnant population of 70 ramets, and a new translocated population of 7 plants. Major threats include disturbance to habitat and plants from erosion and animal activity, *Phytophthora cinnamomi* infection, small population size, lack of genetic variability and apparent lack of fertility. *Borya mirabilis* is listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and as Threatened under the Victorian *Flora and Fauna Guarantee Act 1988*. This recovery plan builds on the framework and guidelines for securing the conservation of *B. mirabilis* set out in the previous recovery plan for this species (Coates 2000). Some of the recovery actions set out in the previous plan are ongoing, whilst others are new objectives. In particular, post-fire management of the population has become critical since the site was burnt in a wildfire in 2006. The population is showing good signs of recovery, but careful management to prevent erosion and *Phytophthora cinnamomi* infection is required.

Species Information

Description

Borya mirabilis is a small, tufted plant with erect stems to 15 cm high, and has linear leaves 10–16 mm long that are clustered at the stem apices, and 3–15 linear, pointed bracts to 13 mm long. The persistent leaf sheaths have fine cottony hairs just below the junction with the leaf blade. The plant has 4–12 tiny white flowers, the perianth tube about 6 mm long, and has linear lobes. The species flowers from September to November (description from Churchill 1985; Conran 1994). *Borya mirabilis* has an association with vesicular arbuscular mycorrhiza (fungal symbionts found on the root systems of many plants that are beneficial to plant growth), which occurs as coils in small nodules on the lateral roots. The species is a xeromorphic and desiccation-tolerant plant (Gaff & Churchill 1976), and is typically in a desiccated state over the warmer, drier months, from November to February. Leaves change colour from green to orange and then yellow as the plants become desiccated. Leaves generally begin to rehydrate in autumn, with the onset of seasonal rains. Plants with this lifestyle are often termed 'resurrection' plants.

Borya mirabilis is likely to be fly-pollinated, as are other species of Borya (Keighery 1984). However, the population appears to consist of only one or two genotypes (Coates *et al.* 2002). Reproduction is thought to be solely vegetative, presumably by adventitious roots that occur on stems, or by separation of sections of the colony. On more vertical sections of rock, *B. mirabilis* colonies appear to be part of lithoseral stages, where bare rock is colonised by algae and crustose lichens, followed by bryophytes, herbs and geophytes that facilitate soil accumulation and subsequent colonisation by deeper rooted or woody species. When the substrate is no longer able to support the increasing weight of the accumulating soil and vegetation, parts or the whole of the colony break away.

Distribution and Populations

Borya mirabilis is confined to the Grampians in western Victoria, in the Victorian Midlands IBRA bioregion (*sensu* DEH 2000) (Figure 1). The species is known from a single remnant population of 70 irregularly-shaped 'clumps' of ramets (which are difficult to separate into individual plants) confined to an area of 60 m x 20 m, in the Wonderland Range, Grampians National Park. A translocated population consisting of seven plants has been established in 2004 in the Mt Difficult Range in the Grampians. Both locations are kept confidential, due to the threat of illegal collection and site disturbance. Maps showing the general distribution of *B. mirabilis* are available from the Department of Sustainability and Environment.

Habitat

The site where *B. mirabilis* grows in the Wonderland Range consists of low open shrubland on a ferruginous sandstone outcrop consisting of a series of rocky terraces (Cropper 1993). Soils are usually dry in summer, but seasonally moist through seepage and impeded drainage which has also caused erosion of the bedrock and contributed to the accumulation of fine sandy loam soil, a relatively rare occurrence in rocky environments, and one that may have favoured the persistence of the population at this site. Soil depth ranges from just a few centimetres up to 1 m. The slope is

approximately 15^0 and faces northeast. Dominant plant species at the site include *Grevillea aquifolium, Kunzea parvifolia, Calytrix tetragona, Melaleuca decussata* and *Dodonaea viscosa* subsp. *spatulata*. Associated species include *Lepidosperma viscosa*, *Gonocarpos mezianus, Phyllanthus hirtellus, Leptospermum scoparium* and*Austrodanthonia setacea*. *Callitris rhomboidea* and *Eucalyptus alaticaulis* are occasional emergents. A number of annual herbs appear in spring, associated with bryophyte and lichen communities, including *Siloxerus multiflora*, *Drosera whittakeri* subsp. *aberrans*, *Dro. peltata* subsp. *auriculata*, *Centrolepis strigosa* and *Cen. aristata*.

Figure 1. Distribution of *Borya mirabilis*

Decline and Threats

Borya mirabilis has only ever been known from a single wild population, so it is not possible to determine if there has been any historic decline in distribution and/or abundance. The original wild and translocated populations face a variety of threats, summarised as follows:

Site disturbance
Disturbance to plants and their habitat is a major threat to *B*. *mirabilis*. Although the site is naturally prone to erosion due to the steep slope and sandy soil (Coates *et al.* 2002), this has been exacerbated in recent years by prolonged drought and occasional heavy rainfall. Additionally, the 2006 wildfire decreased vegetation cover which has also increased erosion. Accelerated erosion of soil due to fire and drought is a significant threat to the survival of *B. mirabilis*, and in the past has been so severe as to leave the plants on pedestals of soil (Coates *et al.* 2002). Soil disturbance is also likely to limit the opportunity for vegetative reproduction, which is the main form of reproduction for this species. Digging by rabbits and echidnas and foraging activities of wallabies also contribute to soil disturbance and erosion. There is the potential for trampling by bushwalkers inadvertently straying onto the site, and also the risk of illegal collection by naturalists visiting the site eager to see this rare plant.

Infection by *Phytophthora cinnamomi*
The plant pathogen *Phytophthora cinnamomi* is present in the vicinity of the wild population, affecting

heathland species such as bush-peas (family Fabaceae) and *Correa* species (Reiter *et al.* 2004). As *B. mirabilis* is a resurrection species, it naturally displays many of the symptoms caused by *P. cinnamomi* (e.g. yellow leaves during desiccation) which makes visual detection of the pathogen difficult. Reiter (2002) isolated *P. cinnamomi* from a soil sample taken from the base of an unhealthy *B. mirabilis* plant and found that *B. mirabilis* is susceptible to infection by the pathogen, which causes chlorosis, browning, reduced vigour and reduced biomass (Reiter *et al.* 2004). There are a number of dead shrubs at the site, but it is unclear as to whether their death is due to *P. cinnamomi,* drought and/or natural senescence. Many native vegetation communities undergo a change in understorey structure, species composition and a decrease in canopy cover as a result of infection by *P. cinnamomi* (Weste *et al.* 2002). This loss of tree, shrub and ground cover over time would further exacerbate soil moisture loss and erosion at the site.

Lack of Genetic Variability/Plant Viability

The *B. mirabilis* population lacks genetic variability and fails to set seed, as pollen viability is low, and those pollen grains that do germinate produce pollen tubes that grow so slowly that effective fertilisation does not occur (Coates *et al.* 2002). Failure (or extremely low rates of success) to reproduce sexually is probably due to the self-incapability between plants of the same genotype. A significant number of flowers appear to be malformed, with shortened stigmas, four petals instead of six and fused anthers. *Borya mirabilis* has about three times the number of chromosomes of its closest relatives, and it is possible that this apparent chromosome abnormality is causing flower malformations resulting in extremely low fertility (N. Reiter RMIT University, pers. comm.). Its small size and single occurrence also render the species particularly vulnerable to extinction due to stochastic events. Resurrection plants also tend to be poor competitors, growing on shallow soils where deeper-rooted, more vigorous species are unable to establish.

Wildfire

The response of *B. mirabilis* to fire is unclear, although fire is thought to threaten its survival (Churchill 1987). A wildfire in the Grampians in January 2006 severely burnt all *B. mirabilis* plants at the Wonderland site (the translocated population was not burnt). Plants have shown signs of recovery since, with 50% of the plants re-sprouting within a few months of the fire. However, recovery has been slowed by a reduction in shade and increased soil drying as a result of the fire, exacerbated by drought conditions, and about one-half of the ramets remain in a desiccated state (2009). As the vegetation is regenerating the site is becoming more shaded and retaining more moisture, and it is likely that most plants will recover. The main issue seems to be related to increased risk of erosion due to loss of vegetation and leaf litter immediately after fire.

Climate Change

Borya mirabilis is a resurrection plant, and has the ability to tolerate desiccation over summer and rehydrate after the onset of autumn rains. However, prolonged drought conditions and increased exposure and drying of the site following summer wildfire seem to have contributed to reduced vigour of plants. Leaf shedding and a gradual decline in the ability of some plants to produce new growth or resurrect fully from a desiccated state have been observed during monitoring. Some Western Australian *Borya* species are known to reduce the impact of prolonged drying by shedding leaves during periods of stress (Churchill 1987), but it is not clear if *B. mirabilis* has this ability. Basal resprouting is observed mostly in plants growing beneath shrubs and in crevices between boulders, in deeper soils where plants are better protected from disturbance and moisture loss. Reduction of rainfall and long-term drying predicted as a result of climate change may be a major long-term threat. In general, resurrection plants such as *Borya* may be unable to recover from a quiescent state that extends beyond a few years, after which time a proportion of cells fail to regenerate, physiological processes critical to revival are disrupted, and ultimately the plant dies (Gaff & Churchill 1976).

Recovery Information

Existing Conservation Measures

A considerable amount of effort has been expended on the conservation of *B. mirabilis*, and the effectiveness and success of the previous recovery plan (Coates 2000) is clearly demonstrated by the list of outputs and management activities detailed below:

- Integration of recovery actions for *B. mirabilis* into the Grampians National Park Management Plan.
- Jute matting was installed in 2006 to slow the movement of surface water from above the remnant site in order to decrease erosion, and the slope has been further stabilised by the

- A proportion of the population most at risk from disturbance by animals was caged to reduce this threat. The need for additional caging is assessed on a regular basis.
- Permanent transects have been established to measure the proportion of resurrected or new shoots, and monitoring conducted at three-monthly intervals.
- An *ex situ* collection of *B*. *mirabilis* was originally established at the Royal Botanic Gardens, Melbourne in the 1970s, but this collection foundered. A new *ex situ* collection was established in 1995, and has been used to propagate plants by cuttings. Tissue culture has been trialled to rapidly increase numbers of plants, but has not been successful to date, with plants failing to form roots (N. Walsh RBG, pers. comm.). Tissue culture techniques are being further examined and trialled, with the possibility of combining tissue culture with traditional propagation techniques (e.g. cuttings) being investigated (N. Reiter RMIT University, pers. comm.). More cuttings from the *ex-situ* collection were taken in May 2007, resulting in 15 new plants, and 25 plants are currently held in cultivation.
- Eight plants were translocated to a site on the Mt Difficult Range in 2004 to establish a new population, with seven currently surviving.
- An investigation into the pollination biology of *B. mirabilis* by researchers at RMIT University is continuing, with the results of about 800 hand crosses in the field currently being analysed.
- Cultivation trials using root samples from field plants indicated that health and shoot number of plants inoculated with the root mycorrhiza were significantly greater than those plants not inoculated. All the associated plants at the field site have been examined for mycorrhizal associations and several species with similar mycorrhiza have been determined; work is currently underway to identify and name the mycorrhiza (Hedy Reiter, pers. comm.). This knowledge will help preserve *B. mirabilis* and aid in the search for new translocation sites.
- Site location is kept confidential to reduce the likelihood of illegal collection and site damage.
- A control strategy to manage the risks posed by *P. cinnamomi* infection was developed and implemented in 2003. To limit *P. cinnamomi* infection of the site, a phosphonate spray (Foli-R-Fos™) was applied to the site until 2006, when it was ceased due to poor plant condition and growth following the fire and drought. Hygiene controls have been implemented to prevent site visitors (scientists, managers) carrying in *P. cinnamomi*. Walking track management and maintenance has occurred to prevent the inadvertent spread of *P. cinnamomi* to the *Borya* site. Interpretive signage on the effects of *P. cinnamomi* was provided for park visitors.
- The site was mulched after the 2006 fire to maintain soil profiles and moisture levels.
- Ground and aerial searches of similar habitat have been conducted since 2003 to search for new populations, although these have been unsuccessful to date.

Recovery Objectives

The overall objective of recovery is to minimise the probability of extinction of *Borya mirabilis* in the wild and to increase the probability of the species to become self-sustaining in the long term. Within the duration of this Recovery Plan, the specific objectives for the recovery of *B. mirabilis* are to:

1. Prevent soil disturbance.
2. Protect plants from infection by *Phytopthora cinnamomi*.
3. Measure plant health against habitat management and post-fire recovery.
4. Investigate pollination biology.
5. Search for new populations.
6. Maintain an *ex-situ* collection.
7. Establish new populations in the wild.

Program Implementation and Evaluation

This Recovery Plan guides recovery actions for *Borya mirabilis* and will be implemented and managed by the Department of Sustainability and Environment and Parks Victoria, supported by other agencies,

educational institutions, regional natural resource management authorities and community groups as appropriate. Technical, scientific, habitat management or education components of the Recovery Plan will be referred to specialist groups on research, *in situ* management, community education and cultivation as required. The Recovery Plan will run for a maximum of five years from the date of its adoption under the EPBC Act, and will be reviewed and revised within five years of the date of its adoption.

Recovery Actions, Priorities and Performance Criteria for *Borya mirabilis*

Action	Description	Performance Criteria	Priority
Specific Objective 1: Prevent soil disturbance			
1.1	Prevent further soil loss and minimise soil drying – techniques include jute matting, mulching using litter from nearby vegetation, translocation of bryophyte mats (tested for physical and chemical properties and screened for *P. cinnamomi*). **Responsibility: PV**	• Measurable decrease in soil loss. • Measurable increase in plant health.	1
1.2	Control disturbance by animals – control rabbit populations; survey for feral goats within the Wonderland Range and control if required; survey to determine whether use of the site by native fauna is a significant threat to the population. **Responsibility: PV**	• Little evidence of soil disturbance by animals. • Plants are not disturbed or dislodged by animal activity.	1
1.3	Investigate realignment of the Mackays Peak walking track to limit public access and disturbance. **Responsibility: PV**	• No visible sign of entry to site by the public.	3
Specific objective 2: Protect plants from infection by *Phytopthora cinnamomi*			
2.1	Treat the wild and translocated sites with phosphonate as required. Maintain hygiene by scrubbing footwear and washing with phosphonate prior to site access. **Responsibility: PV**	• No evidence of *P. cinnamomi* infection evident at sites.	1
2.2	If the Mackey's Peak track above the wild site is not re-aligned, install footwear treatment for walkers on the path above the population. Investigate the pattern of surface water flow and alter if necessary so that contaminated water from the track does not reach the site. **Responsibility: PV**	• No evidence of *P. cinnamomi* infection evident at site.	1
Specific Objective 3: Measure plant health against habitat management and post-fire recovery			
3.1	Assess physiological performance of individual plants each year by comparing the proportions of new or resurrected shoots with dead material in autumn, spring and early summer. Transects divided into 20 x 1 cm intervals permanently are placed through each ramet in the population, and the number of 1 cm intervals with a living or dead shoot are recorded and ratios calculated. **Responsibility: PV, DSE**	• Increase in existing monitoring data.	1
3.2	Conduct site surveys each year to monitor disturbance and habitat response using quantitative methods to measure erosion and post-fire recovery of associated vegetation, and compare these against population performance. **Responsibility: PV, DSE**	• Evaluated plant health against habitat condition.	
Specific objective 4: Investigate pollination biology			
4.1	Investigate the pollen viability, ovary and seed development of embryos. Determine at what stage the embryos are being aborted. Continue chromosomal investigation. **Responsibility: RMIT, RBG**	• Improved knowledge of pollination biology.	1

Specific objective 5: Search for new populations			
5.1	Undertake surveys for new populations – new populations are most likely to be detected in late summer, when plants have desiccated and turned bright orange, so that they are easily identified from a distance. **Responsibility: PV**	• Increase the number of wild populations.	2
Specific objective 6: Maintain an *ex situ* collection			
6.1	Continue to develop propagation techniques. At present only propagation by cuttings is successful. Tissue culture techniques can potentially produce large numbers of plants and at present can produce material with shoots. Further work is required to investigate its potential for producing roots. **Responsibility: RMIT, RBG**	• Plants with roots successfully produced using tissue culture. • Number of plants in collection increased to 50+.	2
6.2	Maintain growing environment such that plants retain their ability to resurrect and prevent cultivated plants from being infected with *Phytophthora cinnamomi*. Propagate new plants using cuttings of *ex situ* plants at RBG. Numbers of plants to be translocated will depend on the extent of available habitat, and cultivation success. **Responsibility: RBG**	• 50 healthy plants suitable for translocation in cultivation	2
Specific Objective 7: Establish new populations in the wild			
7.1	Locate suitable transplant sites by conducting environmental and floristic surveys. Test suitable sites for the presence of *P. cinnamomi.* **Responsibility: DSE, PV**	• At least one suitable site identified.	1
7.2	Translocate cultivated plants to suitable sites to form new population. Monitor the survivorship and life history stages of translocated plants following translocation, with the aim of modifying management if necessary. **Responsibility: DSE, PV**	• Visible survival and growth of transplanted plants.	1
7.3	Using cultivated plants, establish *B. mirabilis* in the Brambuk Aboriginal Centre Indigenous Garden. *Borya mirabilis* has an educational function as a resurrection plant and as a species unique to the area, and can provide a living example of the role of plants and their environment in Koori culture. **Responsibility: RBG, PV**	• Survival, growth and completion of life history stages of five translocated plants in the Indigenous Garden.	3

Abbreviations: DSE = Department of Sustainability and Environment, Victoria; PV = Parks Victoria; RBG = Royal Botanic Gardens, Melbourne; RMIT = Royal Melbourne Institute of Technology (RMIT University)

Management Practices

Management strategies necessary to avoid a significant impact on *B. mirabilis* include:

- Implementing the Grampians National Park Management Plan, especially in-situ site management
- Educational and interpretational activities
- Fire management
- Maintenance of plant cultivation and propagation facilities.

On-ground site management will aim to mitigate threatening processes and thereby insure against extinction. Major threats requiring management include grazing, soil erosion and infection by *P. cinnamomi*. A range of strategies will be necessary to mitigate these threats including mulching of soil, caging/fencing, control of pest animals, and measures to prevent infection by *P. cinnamomi*.

Broadscale protection measures applicable to all populations include legal protection of the site and habitat retention. In addition, searches of known and potential habitat should continue to better define the distributions and size of the population.

The recovery plan also advocates strategies to fill some of the major gaps in our knowledge to date. These include understanding the response of *B. mirabilis* to fire and the pollination biology. Successful *in situ* population management will be founded on understanding the relationship between plant health and post-fire recovery of the site, as well as determining which animals are grazing the site and disturbing the soil. In addition, translocation of cultivated plants to suitable sites will be a major way of boosting the numbers of *B. mirabilis*. Propagation techniques are still being refined with an aim to producing many more new plants for transplant purposes.

Affected Interests

Borya mirabilis occurs only in the Grampians National Park, and management is mainly the responsibility of Parks Victoria. Community participation will be sought during the *ex situ* phases of recovery, by encouraging individuals or groups with demonstrated expertise to assist with propagation and cultivation. Other affected interests include the Department of Sustainability and Environment, Royal Botanic Gardens, Melbourne, RMIT University and the Brambuk Aboriginal Cultural Centre.

Role and Interests of Indigenous People

Indigenous communities on whose traditional lands *B. mirabilis* occurs have been advised, through the relevant DSE Regional Indigenous Facilitator, of the preparation of this draft Recovery Plan and invited to provide comments if so desired. Other opportunities to involve indigenous communities in the implementation of the Recovery Plan will be explored once it is finalised. The Djab wurrung and Jardwadjali Aboriginal communities are the traditional owners of the Gariwerd – Grampians region affected by this plan, and are involved in management of the park. There is an opportunity to use plantings of *B. mirabilis* at the Brambuk Aboriginal Cultural Centre Indigenous Garden. It can be used to highlight the importance of indigenous plants in Koori culture (A. Clarke, Brambuk, pers. comm.). Being a resurrection plant, it can be used to emphasise seasonality in the Australian environment and how Koori culture is defined by seasons different from those of other cultures.

Biodiversity Benefits

Management of the site will contribute to habitat viability and integrity, species richness and protection of other threatened flora associated with *B. mirabilis* (e.g. the rare plants *Austrostipa hemipogon* and *Eucalyptus alaticaulis* also occur at the site). Implementation of the Recovery Plan will contribute to managing potentially threatening processes, such as the plant pathogen *Phytophthora cinnamomi,* which is present in the vicinity of the wild population, and may threaten the future survival of *B. mirabilis*. Implementation of the *B. mirabilis* recovery plan will also contribute to the management of rocky outcrop vegetation, which may face similar issues of soil erosion and disturbance. An understanding of the fire response of the vegetation community in which *B. mirabilis* occurs will aid management of similar sites in the Grampians, including the site supporting translocated plants. Although sites have been burnt in the past, the 2006 fires provide an opportunity to examine how vegetation responds to fire and how this may affect the survival of *B. mirabilis*.

Social and Economic Impacts

The implementation of this recovery plan is unlikely to cause significant adverse social and economic impacts. The two populations occur in the Grampians National Park, managed by Parks Victoria, and management of the locations for conservation of the species is the highest priority.

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References

Churchill, D.M. 1985. Three new species of *Borya* Labill. (Liliaceae). *Muelleria* 6(1): 1–8.

Churchill, D.M. 1987. *Borya*. *Flora of Australia Volume 45, Hydatellaceae to Liliaceae*, pp. 268–277. Australian Government Publishing Service, Canberra.

Coates, F. 2000. Grampians Pincushion Lily (*Borya mirabilis* Churchill) Recovery Plan 2001–2005. School of Botany, La Trobe University, Victoria.

Coates, F., Walsh, N.G., and James, E.A. 2002. Threats to the survival of the Grampians pincushion lily (*Borya mirabilis*, Liliaceae) – a short-range endemic from western Victoria. Australian Systematic Botany 15:477–483.

Conran, J.G. 1994. Liliaceae. In: *Flora of Victoria. Volume 2, Ferns and Allied Plants, Conifers and Monocotyledons* (eds N.G. Walsh and T.J. Entwisle). Inkata Press, Melbourne.

Cropper, S. 1993. *Management of Endangered Plants*. CSIRO, Melbourne.

DEH 2000. *Revision of the Interim Biogeographic Regionalisation of Australia (IBRA) and the Development of Version 5.1. - Summary Report.* Department of Environment and Heritage, Canberra.

Gaff, D.F. and Churchill, D.M. 1976. *Borya nitida* Labill. - an Australian species in the Liliaceae with desiccation-tolerant leaves. *Australian Journal of Botany* 24: 209–224.

Keighery, G.J. 1984. The Johnsonieae (Liliaceae); Biology and Classification. *Flora* 175: 103–108.

Reiter, N. 2002. The susceptibility of seven rare, vulnerable and endangered Grampians native plants to the plant pathogen *Phytophthora cinnamomi*. Honours thesis. School of Botany, Melbourne University.

Reiter, N., Weste, G. and Guest, D. 2004. The risk of extinction from disease caused by *Phytophthora cinnamomi* to endangered, vulnerable or rare plant species endemic to the Grampians, western Victoria. *Australian Journal of Botany* 52: 425–433.

Weste, G., Brown, K., Kennedy, J. and 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.

Estimated Costs of Recovery Actions

Action	Description	Cost estimate					
		Year 1	Year 2	Year 3	Year 4	Year 5	Total
1: Prevent soil disturbance							
1.1	Prevent soil loss/minimise drying	$5,000	$5,000	$5,000	$4,000	$4,000	$23,000
1.2	Control site disturbance	$6,000	$6,000	$5,000	$4,000	$4,000	$25,000
1.3	Re-align Mackey's Peak walking track	$0	$12,000	$0	$0	$0	$12,000
2: Protect plants from infection by *Phytopthora cinnamomi*							
2.1	Protect plants from infection	$5,000	$5,000	$5,000	$5,000	$5,000	$25,000
2.2	Manage Mackey's Peak walking track	$3,000	$2,000	$2,000	$2,000	$2,000	$11,000
3: Measure plant health against habitat management and post-fire recovery							
3.1	Assess plant performance	$6,000	$6,000	$6,000	$6,000	$6,000	$30,000
3.2	Conduct site condition survey	$10,000	$10,000	$10,000	$10,000	$10,000	$50,000
4: Investigate pollination biology							
4.1	Investigate pollination biology	$5,000	$5,000	$5,000	$0	$0	$15,000
5: Search for new populations							
5.1	Search for new populations	$0	$3,000	$3,000	$3,000	$0	$9,000
6: Manage the *ex-situ* population							
6.1	Maintain cultivated population	$3,000	$3,000	$3,000	$3,000	$3,000	$15,000
6.2	Improve tissue culture propagation	$5,000	$5,000	$5,000	$0	$0	$15,000
7: Establish new populations							
7.1	Locate suitable transplant sites	$0	$3,000	$3,000	$3,000	$0	$9,000
7.2	Translocate plants, monitor survival	$0	$0	$5,000	$5,000	$5,000	$15,000
7.3	Establish *B. mirabilis* in BACC garden	$0	$0	$3,000	$0	$0	$3,000
	Totals	$48,000	$65,000	$60,000	$45,000	$39,000	$257,000