Mason's Darwinia
(Darwinia masonii)
Recovery Plan

Wildlife Management Program No. 66
Western Australia
Department of Biodiversity, Conservation and Attractions
December 2018

GOVERNMENT OF WESTERN AUSTRALIA
Department of **Biodiversity, Conservation and Attractions**

Abbreviations

AHD	Australian Height datum
BGPA	Botanic Gardens and Parks Authority
BIF	Banded Ironstone Formation
CAP	Conservation Action Plan
DBCA	Department of Biodiversity, Conservation and Attractions, Western Australia
EPA	Environmental Protection Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EHPL	Extension Hill Pty Ltd
GDTFRT	Geraldton District Threatened Flora Recovery Team
IBRA	Interim Biogeographical Regionalisation for Australia
IRP	Interim Recovery Plan
IUCN	International Union for Conservation of Nature
MGCP	Mt Gibson Conservation Project
MGM	Mount Gibson Mining Limited
MS	Ministerial Statement (Statement that a proposal may be implemented under Western Australian *Environmental Protection Act 1986*)
PEC	Priority Ecological Community
PER	Public Environmental Review
TPFL	Threatened and Priority Flora Database (DBCA)
TSSC	Threatened Species Scientific Committee
VU	Vulnerable Conservation Status
WA	Western Australia
WA Herb	Western Australian Herbarium
WA TSSC	Western Australian Threatened Species Scientific Committee

Foreword

This recovery plan has been developed within the framework laid out in the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA) (formally Parks and Wildlife) Corporate Policy Statement No. 35 (Parks and Wildlife 2015c) and Corporate Guideline No. 36 (Parks and Wildlife 2015b) and the Australian Government Department of the Environment and Energy's Recovery Planning Compliance Checklist for Legislative and Process Requirements (Department of Environment 2014).

Recovery plans outline the recovery actions that are needed to address those threatening processes most affecting the ongoing survival of threatened taxa or ecological communities. The attainment of objectives and the provision of funds necessary to implement actions are subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities.

This recovery plan was given DBCA regional approval on 12 December 2018 and was approved by the Executive Director of Biodiversity and Conservation Science on 14 December 2018. Approved recovery plans are subject to modification as dictated by new findings, changes in status of the taxon, and the completion of recovery actions.

This recovery plan has been prepared in consultation with Extension Hill Pty Ltd (EHPL) and Mount Gibson Mining Limited (MGM) but has not been approved to meet condition 6-3 of Ministerial Statement 753 (MS753), which authorises the implementation of the Mount Gibson Iron Ore Mine and Infrastructure Project.

Information in this plan was accurate at July 2018.

Plan preparation: This plan was prepared by Kiera Foster and Janet Newell (Conservation Officers, DBCA, Geraldton).

Acknowledgements: The following people provided assistance and advice in the preparation of this plan:

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Contents

Summary

Species:	*Darwinia masonii*	**Common name:**	Mason's Darwinia
Family:	Myrtaceae	**Flowering period:**	April – November
IBRA Regions:	Avon Wheatbelt, Yalgoo	**IBRA Subregions:**	Avon Wheatbelt P1, Tallering
Shire:	Yalgoo	**NRM region:**	Rangelands NRM – Murchison subregion
DBCA Region:	Midwest	**Recovery team:**	Geraldton District Threatened Flora Recovery Team
DBCA District:	Geraldton		

Current conservation status of taxon:

- *Environment Protection and Biodiversity Conservation Act 1999*: Vulnerable (VU)
- Western Australia *Wildlife Conservation Act 1950*: Specially Protected Flora under Schedule 1- Flora that are considered likely to become extinct or rare, as Critically Endangered flora
- ranked in Western Australia as Critically Endangered (CR) under International Union for Conservation of Nature (IUCN) 2001 Red List criteria B1ab(ii,iii,v).

Habitat important to survival:

The habitat that is important to the survival of *Darwinia masonii* includes:

- the current area of occupancy of subpopulations in the Mt Gibson Ranges
- areas of similar habitat surrounding and linking subpopulations, that provide potential habitat for subpopulation expansion and for pollinators
- additional occurrences of similar habitat that may contain undiscovered subpopulations or a dormant seed bank of the species or be suitable for future translocations
- any local surface water drainage and infiltration that may affect the habitat of the species.

Threatening processes:

The known and potential threatening processes for *Darwinia masonii* are:

- clearing
- drying climate
- inappropriate fire regimes
- habitat disturbance
- weed invasion
- grazing.

Recovery plan objective:

The objective of this recovery plan is to abate identified threats and maintain or enhance *in situ* subpopulations to ensure the long-term conservation of *Darwinia masonii* in the wild.

Criteria for success

Recovery will be considered successful if, over the term of the plan, all of the following are achieved:

1. There is no reduction in the extent of occurrence, and the number of *in situ* mature individuals within the known subpopulations has remained within a ±15% range or has increased by >15% (with reference to 2014 census).
2. The *in situ* genetic diversity of *D. masonii* has been maintained at pre-mining levels (as per BPGA 2010).
3. Mining has had no indirect impacts on the health of *D. masonii* plants or its habitat outside of approved mining areas.
4. A portion of *D. masonii* habitat/subpopulation has been secured from mining activities through long-term protection mechanisms.

Criteria for failure

Recovery will be considered unsuccessful if, over the term of the plan, any of the following take place:

1. There is a reduction in the extent of occurrence or the number of *in situ* mature individuals within the known subpopulations has decreased by <15% (with reference to 2014 census).
2. The *in situ* genetic diversity of *D. masonii* has declined >2% below pre-mining levels (as per BPGA 2010).
3. Mining has an indirect impact on the health of *D. masonii* plants or its habitat outside of approved mining areas.
4. A portion of *D. masonii* habitat/subpopulation is not secured from mining activities through long-term protection mechanisms.

Recovery actions:
1. Coordinate recovery actions and liaise with stakeholders
2. Secure long-term protection of habitat
3. Maintain seed and germplasm collections
4. Develop and implement translocations
5. Promote awareness of *Darwinia masonii*
6. Implement *Darwinia masonii* condition monitoring program
7. Implement fire management strategy
8. Prevent indirect impacts of mining activities
9. Protect plants from herbivory
10. Continue undertaking research to assist recovery
11. Monitor subpopulations
12. Report any new occurrences of *Darwinia masonii*
13. Review this plan and assess the need for further recovery actions

1. Background

This section provides a summary of information pertinent to *Darwinia masonii* including its description, taxonomy, conservation status, biology and ecology, habitat and distribution and population dynamics.

1.1 Description

Darwinia masonii is an erect shrub 1.5 to 3 m tall, with narrow leaves approximately 1 cm long, which are almost triangular in cross-section. These leaves are closely crowded towards the ends of the branchlets. The flowering inflorescences are approximately 3 cm in diameter and are surrounded by numerous spreading pinkish bracts that are pendulous on the ends of small branchlets. The bracts are broad at the base but narrow to a pointed apex with a distinct midrib. Each bract is approximately 2 cm in length and 5 mm wide at the base. Each tubular flower is about 5 mm long with a style approximately 1.5 cm in length with hairs below the stigma (Brown, Thomson-Dans and Marchant 1998).

1.1.1 Illustrations and/or further information

Brown, A., Thomson-Dans, C. and Marchant, N. (eds). (1998) *Western Australia's Threatened Flora*. Department of Conservation and Land Management, Western Australia.

DEC (2008) *Mason's Darwinia (Darwinia masonii) Interim Recovery Plan 2008-2012*, Department of Environment and Conservation, Western Australia.

Gardner, C.A. (1964) Contributiones Florae Australiae Occidentalis 13. *Journal of the Royal Society of Western Australia* 47, 54-64.

1.2 History, nomenclature and taxonomic relationships

Charles Gardner (Gardner 1964) described *Darwinia masonii* from specimens collected by D. Mason of White Wells Station (now Charles Darwin Reserve) in about 1960. This species is one of 65 Western Australian species of *Darwinia*. The genus is unusual in having a high proportion of species that are considered rare and endangered as a result of intrinsic rarity – i.e. a species that is naturally rare as a result of limiting natural factors such as edaphic requirements and/or breeding biology. *Darwinia masonii* is an intrinsically rare species.

An analysis of phylogenetic relationships in the genus *Darwinia* found that *D. masonii* is most closely related to three *Darwinia* species from the Northern Sandplain and Wheatbelt regions: *D. acerosa*, *D. purpurea* and *D.* sp. Chiddarcooping (S.D. Hopper 6944) (BGPA 2010). This analysis indicated that these species may be closely related and have possibly speciated allopatrically through isolation and subsequent adaptation of a previously widespread species.

1.3 Conservation status

Darwinia masonii was listed as specially protected under the Western Australian *Wildlife Conservation Act 1950* in 1980 and initially ranked as Vulnerable under IUCN Red List criterion D2: very restricted area of occupancy and only one location, with a plausible future threat that could drive the taxon to Critically Endangered or Extinct in a very short time. On 16 January 2018 it was ranked as Critically Endangered (CR) under IUCN Red List criteria B1ab(ii,iii,v) due to it occurring in only one location, its extent of occurrence estimated to be less than 100 km^2 (16 km^2), and there being an observed and projected continuing decline in its area occupied, extent and quality of its habitat, and number of mature individuals.

Darwinia masonii has been listed as Vulnerable (VU) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) since July 2000.

1.4 Biology and ecology

Darwinia masonii is a long-lived plant. Seedling growth patterns are relatively regular, but this changes once the plants become reproductive. Seedlings have a vertical growth direction until 50 to 70 cm tall, with its growing tip persisting from year to year (BGPA 2010). Once the plant starts to reproduce, the flowering heads form on the terminal end of the branches and new vegetative shoots are produced laterally from below the terminal flowering head. Older plants therefore are characterised by spreading, laterally branched canopies, with ever increasing levels of branching complexity. These older plants may experience dying back of branchlets at their extremities during drought years, and branchlet growth within the canopy during good seasons. Their stems are often irregularly shaped, having cracks, swellings, or spongy bark.

The growth rate of *D. masonii* seedlings in plots burnt in 2003 averaged 3.4 cm per year, while the rate of mature and old plants was neutral or negative with an average of -0.9 cm per year during the period between 2007 and 2009 (BGPA 2010). The average growth rate varied for each year, depending on the annual growing conditions. The rainfall in the region is unreliable and *D. masonii* responds opportunistically to rainfall events. Strong growth of vegetative but not reproductive stages has been observed following summer rainfall events (J. Sackmann 2014, pers. comm.).

Darwinia masonii flowers between April and November (Brown *et al.* 1998). Flowering has been recorded for plants as young as six years old, although only 5% of the young plants flowered at that age (BGPA 2010). The percentage of adult plants flowering and the number of inflorescences varies from year to year although the reason for this is unknown. The number of flowers per plant is proportional to the plant's canopy diameter.

Darwinia masonii is thought to be predominantly pollinated by birds, with BGPA (2010) recording pollination by the White-fronted Honeyeater. New Holland Honeyeaters and Western Spinebills have been observed foraging on flowers of *ex situ D. masonii* plants at the Nuts About Natives nursery at Karnup the (B. Croxford 2015, pers. comm., 12 March). *Darwinia masonii* is also capable of self-pollination but the production of outcrossed seed is a critical requirement for self-sustaining subpopulations. A pollen limitation study showed that *D. masonii* preferentially outcrosses and only produces low numbers of selfed seeds (BGPA 2010). In a pollinator exclusion trial and mating system study, *D. masonii* produced autogamous seeds at a low rate (6.6%) with a low outcrossing rate (t_m = 0.17) in the absence of pollinators, but full access to pollinators significantly increased seed set to 23% and the outcrossing rate to t_m = 0.57. The study was unable to unambiguously separate the actions of birds versus insect pollinators, however insect visitation when birds

were excluded resulted in an increase over autogamy for both seed set (14.8%) and outcrossing rate (t_m = 0.45). These results indicate that birds were much more effective pollinators and more common visitors compared with insects, and produced higher rates of seed set and outcrossing (BGPA 2010). No studies have been conducted on germination success or progeny performance of selfed compared with outcross seeds.

Seed production takes place in spring and early summer (BGPA 2010). *S*eed production is moderately low, with between 15% and 30% of developed fruits in an infructescence containing filled seed. BGPA (2010) found a mean number of filled seeds per infructescence of 2 to 4.5, and on average between 25 and 75 seeds were produced per flowering plant.

Seed predation by the larvae of an unknown moth has a significant impact on *D. masonii* seed production, with seed predation rates varying between years from 6 to 22% (BGPA 2010). The moth also prevents fruits from dispersing from infructescences by sewing them together with silk, and they are then retained on the plant for months.

The seeds are dispersed (and buried) by ants (BGPA 2010). Six ant species have been observed moving *D. masonii* seeds, with observations of *Rhytidoponera violacea* indicating an average foraging distance of 3.7 m and a maximum of 10.8 m. BGPA (2010) suggest that ants dispersed the seeds because they are attracted to still-liquid nectar which coats the outside of *D. masonii* fruits. Observations suggest most of the seeds taken by ants are disposed of above ground at the entrances to ant nests, however *D. masonii* seedlings have been observed emerging from buried ant chambers, confirming that some seeds are buried.

Seeds of *D. masonii* have physical and physiological dormancy. Preliminary results of *in situ* seed burial trials which commenced in January 2009 indicate complex germination/dormancy strategies, combining a requirement for physical degradation of the seed coat, environmental (seasonal temperature) cuing - with seeds cycling in and out of dormancy, and smoke-related physiological responses (BGPA 2010). Germination rate of fresh seed is low, but rates of 90% were achieved with seed exhumed after 9 months of burial and treated with smoke water.

Darwinia masonii seeds form soil-stored seed banks, although how long-lived the seeds are in this seed bank is unknown. A germination trial of the soil seed bank (collected to a depth of 5 cm) found an average seedling emergence density of 3.7 seedlings/m^2 (Ruoss 2013). All of these seedlings were from a long unburnt seed bank (~40 years), with none growing from a more recently burnt (7 years) seed bank.

Darwinia masonii plants are killed by fire (Paul Armstrong and Associates 2004; BGPA 2010) then regenerate from soil-stored seed banks. The plants recruit in a single cohort post fire and therefore plant size in a subpopulation correlates with time since last fire (BGPA 2010). However, for the oldest subpopulations (~50 years since fire) there is a spread of plant sizes, which may indicate that there is also some recruitment of plants in the absence of fire. *Darwinia masonii* has also anecdotally been recorded recruiting after soil disturbance (e.g. track construction) unrelated to fire (J. Sackmann 2014, pers. comm.).

There is spatial and temporal variation in mortality of *D. masonii* seedlings post fire. The death rate of seedlings from a 2003 fire was found to range from 2.5% to 15% per year during monitoring between 2007 and 2009 (BGPA 2010). Possible reasons for this variation in seedling mortality include seasonal variation in rainfall, soil water holding capacity and microclimate. There was a high death rate (91% within one year) of *D. masonii* seedlings following an experimental burn in 2009 which may partly have been due to drought over

the following winter. Mortality is rare among mature *D. masonii* plants, although a significant level of mortality (>10% in one site) was observed due to the winter drought in 2010.

Darwinia masonii is extremely hardy and drought tolerant, with ecophysiological adaptations to living in an environment with low water and nutrient availability, including being able to close down transpiration and photosynthetic function to enter a period of physiological dormancy during drought, with the capacity to restore tissues relatively fast as soils wet (BGPA 2010; Ruoss 2013). Roots of *D. masonii* have the capacity to enter large cracks, pores and fissures in regolith and may achieve considerable root depths (BGPA 2010), although Ruoss (2013) found that *D. masonii* plants do not access water from the substrate year-round. *Darwinia masonii* also has been found to have to have an association with Vesicular-Arbuscular Mycorrhizae (VAM) (BGPA 2010), which are likely to help the plants capture nutrients from the soil.

1.5 Habitat and distribution

Darwinia masonii is found within the Mt Gibson Ranges, 350 km north-east of Perth. It is predominantly restricted in its distribution to the upper slopes, crests and ridges of the eleven major hills that comprise the 6 km long range. The area of occupancy is estimated to be 16 km^2 using the IUCN 2km x 2km grid method.

Modelling of the distribution of *D. masonii* against spatially mapped environmental data found that the principal environmental parameters predicting its distribution were slopes greater than seven to eight degrees, elevation over 380 m AHD and all geology types within the Mt Gibson Ranges (primarily ironstone formations) except 'White Rock (unclassified, including granite and its group, acidic dyke rocks, feldspar porphyry and meta-sediments phyllitic rock)' (BGPA 2010). The modelling also identified as suitable habitat some areas where *D. masonii* had not been recorded in the Mt Gibson Ranges and Yandanhoo Hill to the east. More recent surveys have found *D. masonii* in some of these areas on Mt Gibson Ranges (Maia 2014; Eco Logical Australia 2014). BGPA (2010) also reported that the distribution of *D. masonii* may have an association with unmapped sub-surface features such as regolith (soil depth, underlying rock structure) and long-term fire history patterns, and this may also account for the absence of *D. masonii* plants in areas predicted as having suitable habitat.

There have been a number of surveys undertaken of areas with similar geology (Banded Ironstone Formation or chert) and vegetation to that on the Mt Gibson Ranges (Muir Environmental 1995; Bennett Environmental Consulting 2000; Paul Armstrong and Associates 2004; ATA Environmental 2006) which have found no additional locations, suggesting that *D. masonii* is restricted to the Mt Gibson Ranges.

An anonymously collected specimen of *D. masonii* from the locality of Mt Gibson Station is held in the WA Herbarium (PERTH 01105450). The date of collection is unknown, but it must have been collected prior to 1990, when it was entered into the herbarium database (K. Knight 2014, pers. comm.). The location of this specimen is provided as being between 1 and 2 km north-west of Mt Gibson Homestead within the Mt Singleton Range. Also, in 1981, the habitat of *D. masonii* was broadly described as 'the Austin District on Mt Gibson and Mt Singleton to the south-west of Paynes Find on deep, sandy soils' (Blake cited in Muir Environmental 1995). Surveys have been undertaken across these areas on Mt Singleton Range but no plants found (Paul Armstrong and Associates 2004). The species has not otherwise been recorded on deep sandy soils, so these records are considered to be unreliable. All other specimens of *D. masonii* held by the WA Herbarium were collected from the Mt Gibson Ranges.

The habitat where *D. masonii* grows was described by Brown *et al.* (1998) as tall shrublands on yellow-brown clay loams on the Banded Ironstone Formations (BIF). An ATA Environmental (2004) targeted survey recorded *D. masonii* from eight vegetation communities. These were previously identified and mapped by Bennett Environmental Consulting (2000) and included one mallee, six thicket and one heath community:

T1 Dense Thicket of mixed species dominated by *Acacia* species, *Allocasuarina acutivalvis* subsp. *prinsepiana*, *Calycopeplus paucifolius* and *Melaleuca nematophylla* over Low Shrubland in jaspilite rocks and pockets of loam.

T2 Dense Thicket dominated by *Acacia assimilis*, *A. stereophylla* var. *stereophylla*, *A. ramulosa* and *Allocasuarina acutivalvis* subsp. *prinsepiana* over Low Shrubland of *Acacia acuaria*, *Hemigenia buccinata* and *Enekbatus* aff. *cryptandroides* in loam with scattered rocks on the surface.

T3 Dense Thicket dominated by *Acacia assimilis*, *Allocasuarina acutivalvis* subsp. *prinsepiana* and *Melaleuca nematophylla* over Low Shrubland of *Hemigenia buccinata* and *Hibbertia crassifolia* in loam pockets in jaspilite rocks.

T4 Dense Thicket of *Allocasuarina acutivalvis* subsp. *prinsepiana* with occasional *Eucalyptus oldfieldii* over an Open Scrub of Acacia species over Open Shrubland of *Hemigenia buccinata* or Open Herbs of *Xanthosia kochii*.

T5 Thicket of *Allocasuarina acutivalvis* subsp. *prinsepiana* and *Grevillea obliquistigma* with emergent *Callitris columellaris* over Low Shrubland dominated by *Darwinia masonii*, *Hibbertia crassifolia*, *Melaleuca radula* and *Philotheca brucei* over Herbs of *Xanthosia kochii* in loam pockets in dense jaspilite rocks.

T6 Thicket of *Acacia acuaria* and *Acacia stowardii* over Low Shrubland of mixed species with large numbers of *Darwinia masonii* in loam with abundant rocks on the surface.

M4 Very Low Open Shrub Mallee of *Eucalyptus leptopoda* with emergent *Eucalyptus loxophleba* subsp. *supralaevis* over Thicket of *Acacia ramulosa* over herbland of Asteraceae in loam.

HS1 Low Heath of *Ptilotus obovatus* with emergent shrubs of *Acacia stowardii* and *Calycopeplus paucifolius* over Herbs in loamy clay large amongst large boulders.

Meissner and Caruso (2008) conducted a study of the flora and plant communities of the Mount Gibson Range and surrounding ironstone ranges on the Ninghan Pastoral Lease in 2005. Data was collected from 50 permanent quadrats established between September and October of that year to cover the geomorphology, floristic variation and geographical variation across the ranges. Seven community types were defined, four of which were restricted to the Mt Gibson Ranges. *Darwinia masonii* was only present in two of the restricted communities, and it was an indicator species in one of the communities:

Community 5 Open shrublands and shrublands of *Allocasuarina acutivalvis* subsp. *prinsepiana*, *Calycopeplus paucifolius* and *Acacia tetragonophylla* over shrublands of *Philotheca brucei* subsp. *brucei* and *Ptilotus obovatus*. This community consisted primarily of sites on rocky outcrops on upper slopes and hill crests on Mt Gibson Ranges. It was not found on Extension Hill. This was the most species rich community (mean 38.5 +/- 1.2 species per quadrat). Indicator species were *Acacia exocarpoides*, *A. tetragonophylla*, *Cheilanthes adiantoides*, *Darwinia masonii*, *Hakea recurva*, *P. brucei* subsp. *brucei*, *Prostanthera magnifica*, *Prostanthera patens* and *P. obovatus* var. *obovatus*.

Community 6 Open woodlands, shrublands and sparse shrublands of *Allocasuarina acutivalvis* subsp. *prinsepiana*, *Melaleuca nematophylla*, *A. assimilis* subsp. *assimilis* and *Grevillea obliquistigma* subsp. *obliquistigma* over shrublands of *Hemigenia buccinata* and *Leucopogon* sp. Clyde Hill (M.A. Burgman 1207). This community is found mainly on the crests and upper slopes of Extension Hill with mean species richness of 35.1 +/- 0.8 species per quadrat. Indicator species were *Allocasuarina acutivalvis* subsp. *prinsepiana, Cassytha nodiflora, Grevillea obliquistigma* subsp. *obliquistigma*, *Hemigenia buccinata*, *Leucopogon* sp. Clyde Hill (M.A. Burgman 1207), *Melaleuca nematophylla* and *Melaleuca radula*.

The soil types that *D. masonii* can grow in has been trialled by planting *D. masonii* into a range of soil substrates from sand to BIF rock (Ruoss 2013; BGPA 2010). *Darwinia masonii* plants only survived in BIF rock or BIF gravel substrates (not sand or clay). These rocky substrates have significantly higher Organic Carbon and Total Nitrogen than clay or sand and have slower soil drying curves (BGPA 2010).

1.6 Subpopulations

The most recent census of *Darwinia masonii* in 2014 recorded 20,965 individuals, comprising 19,132 (91%) mature, 1580 (8%) juveniles, 188 (<1%) seedlings and 65 (<1%) senescent plants (Eco Logical Australia 2014). Due to mining interests in the Mt Gibson Ranges there have been a number of surveys of *D. masonii* (Bennett Environmental Consulting 2000; Maia 2014; Muir Environmental 1995; Paul Armstrong and Associates 2004). There have only been two complete censuses of the species however, in 2004 (ATA Environmental 2004) and 2014 (Eco Logical Australia 2014). The 2004 census recorded 16,573 individuals comprising of 14,315 (86%) mature, 1725 (10%) seedlings and 541 (3%) senescent plants (ATA Environmental 2004). It is considered that the greater than 30% increase in *D. masonii* numbers between the 2004 and 2014 censuses is largely a result of a different methodology and greater survey extent in 2014 rather than an increase in the *D. masonii* population.

An estimated 1702 plants were taken in the construction of a mine at Extension Hill in 2010. The 2014 census does not include these removed plants, so the original total number of *D. masonii* plants is estimated to have been 22,667 (MGM 2015b). However, the number of plants taken is estimated from the 2004 census data. The greater number of plants found in the 2014 census suggests that the 2004 data may have been an underestimate and therefore there may have been more plants taken than has been estimated (A. Jones 2016, pers. comm.).

Darwinia masonii occurs in 10 subpopulations[1] across the Mt Gibson Ranges. Subpopulation details and number of individuals in each are shown in Table 1. As stated above, variation over time in estimates of the numbers of mature individuals is thought to have largely been due to differences in survey effort or area, rather than actual changes in the number of individuals. The boundaries of some of the subpopulations, in particular Subpopulations 1, 8 and 9, are interpreted differently by different stakeholders and so subpopulation estimates may vary. Also, many of the subpopulations are geographically closer together (<500 m) than DBCA guidelines allow (DEC 2012) but are considered to be separate subpopulations as they form discrete groups on and around different ridgetops. Records from the 2014 census, however, indicate

[1] In this Recovery Plan, *Darwinia masonii* subpopulations are referred to by their DBCA Threatened and Priority Flora database (TPFL) subpopulation numbers (as of July 2018). These TPFL subpopulation numbers have been updated since the *Darwinia masonii* Interim Recovery Plan (DEC 2008b) and consequently differ between the two documents (Table 1).

Table 1. Summary of *Darwinia masonii* subpopulation information, including TPFL subpopulation numbers, herbarium specimens and plant numbers data.

TPFL Pop no.	IRP Pop no.	Date of first record (database)	Broad location description	WA Herbarium specimens (PERTH No.)	Quadrat monitoring site	Year (survey type) / no. of plants adult (juvenile) [dead]	Comment
1	6	01/01/1994 (TPFL)	Iron Hill South	06874460	D4, D5, D6, D7, D8, D24	2001 20 2004 (estimate) 1601 (970) [133] 2013 (partial) 125 2014 (full) 1871 (280)	Majority of area burnt in 2003 bushfire
2	2	11/05/1995 (TPFL)	Extension Hill	07356595	D1	2000 (partial) 4 2001 (full) 1325 2004 (full) 1924 (12) [25] 2014 (full) 1774 (102)	Part of the subpopulation (1145 plants) was taken for the Extension Hill mine in 2010
3	1	11/05/1995 (TPFL)	Extension Hill North	05313368; 06874495		1995 (estimate) 180 1996 (partial) 10 2000 (partial) 21 2001 (estimate) 350 2004 (full) 545 (12) [12] Present 0	Subpopulation taken for the Extension Hill mine in 2010
4	3	01/10/2003 (TPFL)	Extension Hill South		D2, D3, D16, D17, D18	2003 (full) 1103 2004 (full) 1874 (26) [32] 2014 (full) 1969 (113)	
5 (A, B)	7	10/1950 (WA Herb)	Iron Hill East	01005820; 01005382; 01005790; 01005367; 01005812; 01005359; 01005804; 01005855; 01005375; 01005839; 01005340; 01005847; 00137626; 00719536; 02521741; 02521733; 06796680; 01000691		1987 (estimate) 300 1995 (estimate) 1000 2001 (estimate) 1000 2004 (full) 70 (11) [8] 2014 (full) 1430 (243)	Majority of area burnt in 2003 bushfire
6 (A, B, C)	8	28/07/1986 (WA Herb)	Mt Gibson	07290810; 04977025	D9, D10, D11, D12, D21, D22, D23	2003 (estimate) 2868 2004 (full) 7021 (61) [278] 2014 (full) 9060 (703)	Some of area burnt in 2003 bushfire
7	9	01/01/1994 (TPFL)	Mt Gibson South		D13, D14, D15	2001 (full) 793 2004 (full) 324 (1) 2013 (full) 874 [1] 2014 (full) 852 (30)	
8	5	11/05/1995 (TPFL)	Iron Hill Middle	06874509		1995 (estimate) 200 (19) 2001 (estimate) 100 2004 956 (630) 2014 648 (90)	
9	4	11/05/1995 (TPFL)	Iron Hill North		D19	2004 586 (33) [34] 2014 1034 (179)	
10	Not listed	12/2/2008 (TPFL)	E of Extension Hill South			2013 (partial) 43 2014 559 (28)	

that there may be physical connections between some subpopulations (Populations 2, 4 and 10, and 5, 6, and 7). Therefore, the TPFL subpopulation boundaries should be reviewed in conjunction with the results of unpublished genetic work that indicates genetic distinction between the current TPFL subpopulations (M. Barrett 2013, pers. comm.).

1.6.1 Population genetics

Initial research on the population genetics of *Darwinia masonii* found low genetic differentiation demonstrating weak structure between seven groups of *D. masonii* plants (BGPA 2010). Analysis of Molecular Variance (AMOVA) partitioned 94% of the variation within the groups, and 6% between groups, using both AFLP (Amplified Fragment Length Polymorphism) and microsatellite markers. However, pairwise permutation tests between each of the tested groups revealed significant genetic divergence among some of the groups with microsatellite markers. Two groups (Subpopulations 4 and 7), located on Extension Hill South and Mount Gibson South, were found to be statistically different from each other and all remaining sampled groups, suggesting that they are genetically isolated (BGPA 2010). The distinction between groups may be due to: geographic disjunction; age of the subpopulation since fire causing the results to be skewed by older samples; and differential selection at loci linked to some microsatellite markers. As a result of this finding, BGPA (2010) recommended that genotypes of respective groups should not be mixed in species restoration activities. It should be noted that *Lepidosperma gibsonii* also showed genetically disjunct groupings in the same locations (i.e. Extension Hill South and Mount Gibson South; BGPA 2010). This alignment between the two species suggests that the genetic differences may be due to external influences such as soil type, soil water relations *etc*. that may cause a difference in flowering phenology between sites (G. Dale 2015, pers. comm., 10 March).

The genetic assessment conducted by BGPA (2010) has since been superseded by a more extensive dataset and analysis (M. Barrett 2013, pers. comm.). Results from this more recent population genetic assessment of *D. masonii* indicate a weak but distinct subpopulation differentiation (90% of variation was contained within subpopulations, and 10% between subpopulations), with nearly all subpopulations exhibiting isolation-by-distance (M. Barrett 2013, unpublished data). This suggests that both seed and pollen dispersal are quite localised and occur mainly within subpopulations. Two major groups of subpopulations were identified, divided between the northern (Extension Hill north and south) and southern (Iron Hill and Mt Gibson and adjacent peaks) parts of the range. These findings imply that some of the genetic diversity of *D. masonii* is unique to individual subpopulations, with the inference that the loss of any one subpopulation may reduce the genetic diversity of the species. Based on this, it has been recommended that the genetic structure among separate subpopulations should be maintained (K. Atkins, 2015, pers. comm. 15 Dec.).

A review of the above genetic assessment was undertaken by Verterra (2015) for Mount Gibson Mining (MGM) to provide recommendations for *D. masonii* conservation. This review was contrary to previous recommendations, and concluded that compared with case studies of other plant species (both rare and widespread), *D. masonii* has a relatively low level of genetic divergence between subpopulations, relatively high gene flow and high level of allelic diversity. Based on this, Verterra (2015) recommended that 'the conservation of *D. masonii* would be best served by a strategy that maximises whole-of-population genetic diversity by:

1. Sampling germplasm from across the range (thereby capturing representative samples of both nuclear allelic and chloroplast haplotype variants); and
2. Promoting inter-breeding of genotypes to the greatest possible extent to facilitate inter-mixing of the available pool of common and rare alleles, and thereby preserve the evolutionary potential of the species to adapt to changing environmental, climatic, biological and anthropogenic conditions.'

Verterra (2015) concludes that *ex situ* collections should aim to 'capture "genes" as opposed to genotypes' from both the mine development areas and undisturbed areas, and that these could be mixed in translocations to promote subpopulation mixing 'to preserve genetic diversity and evolutionary potential of the species in the face of changing natural and anthropogenic influences'. However, Verterra's (2015) conclusions have been made in the absence of any data on the potential for outbreeding depression or selective adaptation to environmental conditions on different ridges. If either of these situations are a feature of *D. masonii* subpopulations, they may negate potential gains from promoting intermixing among subpopulations.

Given the lack of evidence to support the recommendations by Verterra (2015), the genetic management approach suggested by the data analysis undertaken by M. Barrett (2013, unpublished data) is recommended to be maintained in the implementation of this recovery plan; that is, the maintenance of existing genetic structure among separate subpopulations.

1.6.2 Factors affecting population dynamics

Fire

Darwinia masonii is killed by fire and then regenerates from its soil-stored seed bank (BGPA 2010), so its fire history can be used to determine the age of a subpopulation. There have been four major fires across the Mt Gibson Ranges since 1969. These were in 1969, 1972, February 2003 and December 2005 (the dates of the first two fires are uncertain and could vary by a year or two). The intensity and patchiness of these fires is unknown. A small two hectare experimental fire was also conducted in 2009 over part of Subpopulation 2 for research into the rate of recruitment and seedling survival.

Approximately 60% of the area of occupancy of *D. masonii* (calculated from 2004 and 2014 census data) has been burnt by at least one of the four known fires, with 11% of the species' total area of occupancy burnt by two of the fires (the main overlap among these fires occurred with the 1969 and 2003 fires). Both the 1969 and 2003 fires burnt approximately one third of the species' area of occupancy (34% and 33% respectively), while the 1972 and 2005 fires had minimal impact (4% and <1% of area of occupancy respectively).

Over 85% of *D. masonii* plants recorded by the 2014 census occur within areas burnt by at least one of the four known fires, leaving about 15% of *D. masonii* in vegetation over 50 years old. Over 73% of *D. masonii* are in nearly 50 year old vegetation (1969 fire). Only 5% of plants are in areas burnt in 1972 (45 years ago), and 27% of plants are in the 2003 burn area (14 years ago). Twenty percent of recorded plants are in areas that were burnt by both the 1969 and 2003 fires (i.e. 34 year fire interval).

Subpopulation 7 is the only subpopulation of *D. masonii* which has not been burnt at all by at least one of the four known fires. Most of Subpopulation 8 and a large area of Subpopulation 1 have also not been burnt by these fires. The 1969 fire impacted most of the eastern ridges of the range (Subpopulations 2, 4, 5, 6, and

10), while the 2003 fire impacted the southern ridges (Subpopulations 1, 5 and 6). The 1972 fire was predominantly to the west of the range though it did burn most of Subpopulation 9. The 2005 fire was to the north of the range and only impacted a small part of Subpopulation 3.

Mining and Infrastructure Development

The Mt Gibson Ranges are part of a series of small ironstone ranges in the Yilgarn Craton. The rocks of these ranges, known as Banded Iron Formation (BIF), contain iron ore. Hematite/goethite mineralisation occurs to varying degrees throughout the Mt Gibson Ranges, formed by weathering of the BIF and removal by dissolution of much of the original silica. Zones rich in primary magnetite have weathered to form significant near-surface deposits of massive hematite-goethite such as those identified at Extension Hill, Iron Hill, and the south flank of Mt Gibson. Many small deposits with limited surface expression also exist, however further drilling is required to determine their extent (MGM 2015a).

The first mine in the range, the Mt Gibson Iron Ore Mine and Infrastructure Project (known as Extension Hill) managed by MGM and Extension Hill Pty Ltd (EHPL), was approved in 2007 (Ministerial Statement No. 753). This included approval to take 1040 ha of vegetation (251 ha for the mine pit) and approximately 2100 *D. masonii* individuals (17% of known population). It is estimated that 1,702 *D. masonii* plants have been taken to date.

A second mine, the Mt Gibson Range Mine Operations Iron Hill Deposits managed by MGM, was approved in December 2016 (Ministerial Statement No. 1045). This included approval to clear 87 ha of vegetation and take 1,327 individuals of *D. masonii* (6% of known population). MGM (2015b) states that this will increase the total number of plants approved to be taken for mining to 22% of the known *D. masonii* population (as of 2014 population census).

However, the cumulative impact on *D. masonii* of these two mines is likely to be 26%, rather than MGM's estimate of 22%, as MGM used two different censuses with different methodologies to calculate the proportional impact (2004 census for the estimate of numbers taken for Extension Hill mine, and 2014 census for estimate of Iron Hills impacts) (A. Jones 2016, pers. comm.). The impact on the area of occupancy or habitat was also not provided in the Iron Hill Public Environmental Review (PER) (MGM 2015b). The cumulative impact of the two mines has resulted in a 38% reduction in the area of occupancy (A. Jones 2016, pers. comm.).

Individuals of *D. masonii* in the vicinity of mining activities may be at risk from indirect impacts including dust, changed microclimate, changed hydrology, changed ecosystem processes including impacts to pollinators and reproductive success, reduced genetic diversity, fragmentation, introduced weeds/disease, increased grazing pressure and changes in seed dispersal (MGM 2015b). Condition monitoring since 2010 by MGM has not revealed any detectable indirect impacts on individuals of *D. masonii* from activities associated with mining (Astron 2014), however there are a number of limitations to the monitoring and analysis of its data (see Section 6 of this Recovery Plan).

Planting trials and translocations

The approval conditions for both current mines on Mt Gibson Ranges (Extension Hill and Iron Hill) require the proponents to offset direct impacts on *D. masonii* through 'regeneration, re-establishment or translocations on suitable un-impacted areas of BIF' (MS 753).

Several translocation trials have been undertaken, using plants grown from clones of the genotypes sourced from Subpopulations 1, 2, 3 and 8 including:

i. A trial translocation investigating the effects of irrigation and herbivores was established in May 2005 in a fenced plot at Iron Hill East (BGPA 2010). It was shown that watering of individuals over the first two summers significantly increased their survival and growth rates, with 81% of those watered still alive in 2014, without having been watered for seven years (J. Sackmann 2014, pers. comm., 6 May). None of the unwatered individuals survived. Two young individuals have since recruited outside of the fenced plot (J. Sackmann 2016, pers. comm., December), though it is unknown whether the plants have recruited from the translocated plants or the nearest wild subpopulation.
ii. A trial investigating establishment on different soil substrates was initiated in the winter of 2009 north of the Extension Hill mine (BGPA 2010). By April 2010, the only *D. masonii* surviving were those planted in BIF rock and BIF gravel sites. None had persisted in sand or clay sites. In 2014, plants were still present at the BIF rock and BIF gravel trial sites (J. Sackmann 2014, pers. comm.).
iii. Ruoss (2013) undertook a trial planting of *D. masonii* (propagated from cuttings) into four different soil substrates varying in rock and clay content. After 20 months there was no survival of *D. masonii* on sand or clay plain sites, while there was a survival of 38% and 23% in the rocky ridge and gravel slope sites respectively. Most of the mortality occurred over the first summer.
iv. In September 2015, 20 *D. masonii* plants were translocated onto the Extension Hill waste rock landform for a waste dump survival trial. The young plants were mostly plants that had grown in the topsoil stockpiles (J. Sackmann 2016, pers. comm., 21 Nov.). As of 22 February 2018, all plants were still alive and most were producing flowers and fruits, however most fruits were unfilled (MGM 2018).
v. Four *D. masonii* translocations were undertaken by MGM in winter/spring 2016, using cuttings from either the Extension Hill or Iron Hill areas, into disturbed areas (old exploration tracks or drilling pads) on the range. Further translocations were planned for 2017.

These trials have shown that *D. masonii* can be planted and survive in a restoration situation. It remains unknown what the long-term viability of these translocations will be, although it appears the 2005 translocated subpopulation may be recruiting (J. Sackmann 2016, pers. comm., December). As BIF endemics such as *D. masonii* have specific habitat requirements and demographic patterns, there is doubt in the likelihood of translocations onto waste dumps being successful in the long term (Yates *et al.* 2011; Gibson *et al.* 2015).

2. Habitat important to survival

Darwinia masonii is known from only one location, the Mt Gibson Ranges in Western Australia. Consequently, it is considered that known habitat for all wild subpopulations is important for the survival of the species and that all wild subpopulations are important subpopulations. Habitat important for the survival of *Darwinia masonii* includes:

- the area of occupancy of subpopulations
- areas of similar habitat surrounding and linking subpopulations (these providing potential habitat for subpopulation expansion and for pollinators)
- additional occurrences of similar habitat that may contain undiscovered subpopulations or a dormant seed bank of the species or be suitable for future translocations
- any local surface water drainage and infiltration that may affect the habitat of the species.

BGPA's (2010) modelled distribution of *D. masonii* against spatially mapped environmental data is the best information available on the habitat important for survival of the species. The modelling predicted *D. masonii* to potentially occur broadly across the Mt Gibson Ranges with a high probability (60 to 75%) of occurrence (BGPA 2010).

3. Threatening processes

Under the *EPBC Act* a threatening process is defined as a factor that threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community. The threatening processes listed below were identified through a combination of best available knowledge and current understanding and are identified as of most significant concern to the survival of remaining *Darwinia masonii:*

- clearing
- drying climate
- altered fire regimes
- habitat disturbance
- weed invasion
- grazing.

One additional factor was identified as a risk to the efficient and effective implementation of recovery efforts for *D. masonii*:

- limited habitat (currently known only to occur on the Mount Gibson Ranges).

3.1 Risk assessment

The risk of each of the threatening processes impacting *Darwinia masonii* under past and present recovery actions was assessed and prioritised to allow the recovery actions and management practices of this plan to be focused where they are most needed.

Analysis and rating of the risk of the threatening processes on *D. masonii* was undertaken using the *Open Standards for the Practice of Conservation* guidelines (CMP 2013). This involved assessing the risk of each of the threatening processes for *D. masonii* over the next 10 years based on three criteria:

- scope (proportion of subpopulations expected to be affected)
- severity (the degree to which the subpopulations are expected to be affected)
- irreversibility (degree to which the effects can be reversed).

Further details of this ranking methodology are included in Appendix 1. The analysis and ranking of threats was based on best available knowledge and current understanding of impacts from individual threatening processes upon *D. masonii*.

The threat ratings to *D. masonii* under the past and present recovery actions for each of the threatening processes are shown in Table 2. Clearing (removal of plants) and drying climate were assessed as the most significant threats. These ratings relate to the magnitude of the threat to the species and its reversibility over the 10-year timeframe of this plan.

Table 2. Summary of the risk of threatening processes to *Darwinia masonii* under past and present recovery actions over the next 10 years.

Darwinia masonii	Clearing	Drying climate	Altered fire regimes	Habitat disturbance	Weed invasion	Grazing
Scope	Medium	Very High	Low	Low	Low	Low
Severity	Very High	Medium	High	Low	Low	Low
Irreversibility	Very High	High	Medium	High	Low	High
RISK RATING	High	Medium	Low	Low	Low	Low

3.2 Threatening processes

3.2.1 Clearing

The known habitat for *Darwinia masonii* comprises ironstone formations that are prospective for iron ore and are under live mining leases. Mining approvals to date (Extension Hill and Iron Hill) on the Mt Gibson Ranges will result in the clearing (direct removal) of up to 3427 *D. masonii* individuals (26% of the known population). The full extent of the iron ore deposits in relation to the distribution of *D. masonii* is yet to be discovered, though MGM has identified other potential deposits in the Range (MGM 2015a).

Further clearing resulting from future exploration and mining operations has the potential to directly impact the conservation status of *D. masonii* by reducing the total population size, genetic diversity, area of occupancy of the species, and the condition of the habitat from exploration activities.

3.2.2 Drying climate

Mortality among mature *Darwinia masonii* plants is rare except possibly during drought conditions. A winter drought in 2010 contributed to a significant level of mortality of mature *D. masonii* plants, with the death of up to 10% of plants marked for a pollination study on Mt Gibson South (BGPA 2010).

Darwinia masonii seedlings may be less resilient to drought conditions than mature plants. BGPA (2010) reported that only 9% of the seedlings that were tagged within recruitment plots of a 2009 experimental fire were still alive in October 2010. They stated that this low survival rate may partly result from the drought experienced over the 2010 winter at Mt Gibson, as well as a likely high failure rate of establishing young seedlings (BGPA 2010).

Long term climate projections for the central parts of WA suggest that annual rainfall may remain relatively unchanged, but that winter rainfall will decrease with increased intensity of extreme rainfall events (Department of Agriculture and Food 2015; CSIRO 2016). The area's already variable climate is predicted to become more variable with wet years likely to become less frequent and dry years (drought) more frequent.

A changing climate, particularly a greater frequency of dry years, could have significant implications for *D. masonii*. It may, for example, result in an increase in adult mortality rate and lower seedling survival, which could impact the species' population size, demography, and breeding biology.

3.2.3 Altered fire regimes

Darwinia masonii is a re-seeder species that is killed by fire and then recruits from soil-stored seedbanks in a single cohort post-fire, with limited inter-fire recruitment (BGPA 2010). The species has complex germination/dormancy strategies, combining a requirement for physical degradation of the seed coat, environmental (seasonal temperature) cuing (with seeds cycling in and out of dormancy), and smoke-related physiological responses.

Darwinia masonii appears to require fire to stimulate significant recruitment, however fire could also be a significant threat to the species at an inappropriate frequency, intensity or season. The youngest age at which plants have been recorded to flower is six years old, but only a small percentage of plants flower at that age, and flower numbers are very low (BGPA 2010). Large old plants with wide canopies produce the most flowers. *Darwinia masonii* was found to recruit from ~40 year old but not from seven year old soil seed banks (Ruoss 2013), suggesting that the species requires much longer than a seven year inter-fire interval for post-fire subpopulation regeneration to occur. The only known fire interval is 34 years between the 1969 and 2003 fires, in which 20% of *D. masonii* individuals currently occur. The majority of the current *D. masonii* population occurs in vegetation that is nearly 50 years old (1969 fire) or older.

3.2.4 Habitat disturbance

Potential indirect impacts of mining include dust, changed microclimate, changed hydrology, changed ecosystem processes including impacts to pollinators and reproductive success, reduced genetic diversity, fragmentation, introduced weeds/disease, increased grazing pressure and changes in seed dispersal (MGM 2015b). MGM (2015b) assessed, for the Iron Hill mine, that uncontrolled fire, weed infestations, prolonged dust emissions and broad areas of altered micro-climate/hydrology were the most likely stressors that may have indirect impacts on *Darwinia masonii* or its habitat.

For current mining at Extension Hill, MGM are implementing management actions to reduce the risk of indirect impacts, such as dust suppression, through their *Darwinia* Management Plan (MGM and EHPL 2008a) and Environmental Management Plan (EMP) (MGM and EHPL 2008b). This includes regular dust monitoring and health checks of *D. masonii* in the vicinity of the mine. Survivorship, health condition and height of *D. masonii* across the range have also been monitored annually since 2007. Analysis of these data by Astron Environmental Services (2014) found that 'the spatial and temporal variation in survivorship, health condition and height of *D. masonii* was not likely to be related to activities at the mine pit', although there were a number of limitations to the monitoring and data analysis (see Section 6).

Further habitat disturbance arising from future mining operations could also potentially have indirect impacts on *D. masonii*. Mitigation of these threats (similar to that of the Extension Hill mine) may maintain the risk as low.

3.2.5 Weed invasion

No significant weed invasion has been observed to date, although there are small populations of weeds in some areas of the range (J. Sackmann 2014, pers. comm.). Weed invasion after disturbance (e.g. fire or clearing of tracks) is a potential threat to *Darwinia masonii*. Weed invasion is also a potential threat to the integrity of the habitat that is important for the species.

3.2.6 Grazing

Although BGPA (2010) and MGM's annual monitoring have found that grazing by vertebrates does not currently impact *Darwinia masonii* (J. Sackmann 2014, pers. comm.), vertebrates including rabbits and feral goats are present within the Mt Gibson Ranges. Rabbits and goats have the potential to impact on the vegetation in the region, including the integrity of *D. masonii* habitat. Grazing is identified here as a potential future threat to *D. masonii*.

BGPA (2010) found no evidence of insect damage to *D. masonii* except galls on a very small number of individual plants. Termites were observed on up to 15% of plants at one site, however their impact did not appear to be significant and growth rates did not seem to be impacted.

4. Broader biodiversity benefits

Recovery actions implemented to abate identified threats and maintain or enhance *in situ* subpopulations to ensure the long-term conservation of *Darwinia masonii* in the wild should also maintain or improve the status of the associated native vegetation and habitat.

The vegetation of the Mt Gibson Ranges that *D. masonii* occurs in is biologically diverse and includes several vegetation communities that are restricted to the Ranges (Meissner and Caruso 2008). These are listed by DBCA as a Priority 1 Ecological Community '*Mt Gibson Range vegetation complexes (banded ironstone formation)*' (3216 hectares total). For a description of Priority Ecological Community (PEC) categories see Parks and Wildlife (2015a).

Two threatened and eight priority flora taxa occur within 500 m of *Darwinia masonii* (Table 3).

Table 3. Conservation–listed flora species occurring within 500 m of *Darwinia masonii*

Species name	Conservation status (WA)	Conservation status (EPBC Act)	Source of record
Eucalyptus synandra	Threatened (VU)	VU	MGM/EHPL; TPFL; WA Herb
Lepidosperma gibsonii	Threatened (EN)	-	MGM/EHPL; TPFL; WA Herb
Acacia cerastes	Priority 1	-	MGM/EHPL; TPFL; WA Herb
Philotheca nutans	Priority 1	-	TPFL; WA Herb
Allocasuarina tessellata	Priority 1	-	MGM/EHPL
Podotheca uniseta	Priority 3	-	TPFL; WA Herb
Rhodanthe collina	Priority 3	-	WA Herb
Verticordia venusta	Priority 3	-	TPFL; WA Herb
Micromyrtus trudgenii	Priority 3	-	MGM/EHPL
Persoonia pentasticha	Priority 3	-	MGM/EHPL; WA Herb

Three fauna taxa listed under the *Wildlife Conservation Act 1950* (WA), and five priority fauna taxa have previously been recorded to occur within the range of *D. masonii* subpopulations (Table 4).

Table 4. Conservation–listed fauna species occurring within the range of *Darwinia masonii*

Species name	Conservation status (***Wildlife Conservation Act 1950***)	Conservation status (***Environment Protection and Biodiversity Conservation Act***)
Leipoa ocellata (Malleefowl)	Threatened (VU)	VU
Cacatua leadbeateri (Major Mitchell's Cockatoo)	Other specially protected fauna	-
Falco peregrinus (Peregrine Falcon)	Other specially protected fauna	-
Aganippe castellum (Tree-stem Trapdoor Spider)	Priority 4	-
Charadrius rubricollis (Hooded Plover)	Priority 4	-
Hylacola cauta subsp. whitlocki (Shy Heathwren (western))	Priority 4	-
Oreoica gutturalis subsp. *gutturalis* (Crested Bellbird (southern))	Priority 4	-
Pomatostomus superciliosus subsp. *ashbyi* (White-browed Babbler (w. wheatbelt))	Priority 4	-

The implementation of recovery actions for *D. masonii* to date and into the future is not anticipated to have any negative effects on other conservation significant taxa and the PEC.

5. Recovery objectives

5.1 Plan objective

The objective of this plan is to abate identified threats and maintain or enhance *in situ* subpopulations to ensure the long-term conservation of *Darwinia masonii* in the wild.

5.2 Recovery criteria

Criteria for success

Recovery will be considered successful if, over the term of the plan, all of the following are achieved:

1. There is no reduction in the extent of occurrence, and the number of *in situ* mature individuals within the known subpopulations has remained within a ±15% range or has increased by >15% (with reference to 2014 census).
2. The *in situ* genetic diversity of *D. masonii* has been maintained at pre-mining levels (as per BPGA 2010).
3. Mining has had no indirect impacts on the health of *D. masonii* plants or its habitat outside of approved mining areas.
4. A portion of *D. masonii* habitat/subpopulation has been secured from mining activities through long-term protection mechanisms.

Criteria for failure

Recovery will be considered unsuccessful if, over the term of the plan, any of the following take place:

1. There is a reduction in the extent of occurrence or the number of *in situ* mature individuals within the known subpopulations has decreased by <15% (with reference to 2014 census).
2. The *in situ* genetic diversity of *D. masonii* has declined >2% below pre-mining levels (as per BPGA 2010).
3. Mining has an indirect impact on the health of *D. masonii* plants or its habitat outside of approved mining areas.
4. A portion of *D. masonii* habitat/subpopulation is not secured from mining activities through long-term protection mechanisms.

6. Existing conservation measures

6.1 Management practices and policies

Management practices (policies, strategies and plans) that have a role in the management of threatening processes and would contribute to the long-term viability of *Darwinia masonii*, but are not actions specifically required for recovery, include, but are not limited, to the following:

- Strategic Review of the Banded Iron Formation Ranges of the Midwest and Goldfields (DEC and DOIR 2007)
- Corporate Policy Statement No. 35 Conserving threatened species and ecological communities (Parks and Wildlife 2015c)
- Corporate Guideline No. 36 Recovery of threatened species through translocation and captive breeding or propagation (Parks and Wildlife 2015b)
- Significant Impact Guidelines 1.1 – Matters of National Environmental Significance (DEWHA 2013)
- WA Environmental Offsets Guidelines 2014 (WA 2014)
- *Lepidosperma gibsonii* Interim Recovery Plan (DEC 2008a)

6.2 Past and existing recovery actions

An Interim Recovery Plan (IRP) was developed for *Darwinia masonii* in 2008 (DEC 2008b). A summary of implementation of each of the recovery actions in the IRP as of January 2017 is included below.

1. **Coordinate recovery actions and liaise with stakeholders**

As a requirement of Condition 6 of MS 1538 for the Extension Hill mine (2007), MGM and EHPL are required to develop and implement an IRP (DEC 2008b), a Research Plan (BGPA 2008) and a Recovery Plan (referred to as a 'Conservation Action Plan') (in prep). Under Condition 7 of MS 1045 for Iron Hill (2016), MGM are also required to write and implement an Offset Plan. Due to these ministerial requirements, MGM and EHPL have been coordinating and implementing most of the recovery actions that have been undertaken for *D. masonii*, in consultation with DBCA, BGPA and other stakeholders.

2. **Continue implementation of the *Darwinia masonii* research programme**

MGM and EHPL are required under Conditions 6-1 and 6-4 of MS753 respectively, to prepare and implement a *D. masonii* Research Plan. To address these conditions, BGPA (2010) undertook a *D. masonii* research project between 2007 and 2010 that included research on conservation genetics, population demography, breeding biology, population viability analysis, environmental interactions and plant health, and restoration ecology. The findings of this research provided significant information on the ecology of this species, as described in Section 1 of this plan.

There have since been two PhD projects undertaken that related to restoration ecology at Mount Gibson with reference to *D. masonii:* Sacha Ruoss (2008 to 2011) (Ruoss 2013) and Sabastian Lamoureux (2013 to 2016).

Robert Archibald from Astron Environmental Consulting currently is working with MGM to trial chlorophyll fluorescence techniques to monitor plant health of *D. masonii* (T. Collie 2016, pers. comm.)

3. Establish and implement *Darwinia masonii* condition monitoring programme

The condition of some *D. masonii* plants not directly impacted by the Extension Hill mine (MGM and EHPL 2008a) has been monitored annually (except 2012) since 2007. As of 2014 there were 35 monitoring plots ranging from 300 m to 4.5 km from the mine pit, however not all of the plots have been monitored annually, with only six of the sites containing data from all monitoring field visits (Astron 2014). In these plots the *D. masonii* plants are tagged and the data collected includes plant height (or length for prostrate plants), reproductive status, plant age, plant condition and seedling recruitment and mortality. In 2007 the monitoring was established with a representative subset of at least 5% of the pre-mining adult population (378 plants in 15 plots) (MGM and EHPL 2011), which has increased to 920 plants in 2014 (MBS Environmental 2015). However not all of the original plants are still monitored due to some individuals not being relocated and/or missing tags.

Four monitoring plots within Subpopulation 4, closest to the Extension Hill mine site, are monitored monthly to allow comparisons between plant health and monthly dust deposition monitoring. At each plot, a photograph is taken and the health of *D. masonii* plants and the surrounding vegetation scored using a scoring matrix developed by BGPA (MGM and EHPL 2008a). Evidence of grazing or weed invasion is also recorded. The three plots closest to the mine site are visually inspected and photographed weekly to monitor for changes in *D. masonii* individuals or general vegetation condition.

An assessment of the 2007 to 2013 monitoring data was undertaken to determine whether there has been any indirect impacts of the mine on the survivorship or health of the *D. masonii* (Astron 2014). Significant spatial and temporal variation in survivorship, health condition and height of the plants was found, however it was concluded that this was not likely to be related to activities at the mine pit. The assessment was limited by small sample size, no sites being close to the mine pit, and not taking environmental factors such as rainfall and fire history into account. Astron (2014) concluded that there was no evidence that the mining activity is impacting on the *D. masonii* as summarised by the following statements:

- 'There was strong temporal variation in survivorship, health condition and height of *D. masonii* between August 2007 and November 2013. Reduced survivorship and poor health condition were observed in 2010 and 2013.
- Some individuals of *D. masonii* died sometime around 2010 across most of the monitoring sites (disturbance at the mine pit began during 2010). Survivorship of *D. masonii* at monitoring sites on Mt Gibson South, which was more than 2 km from the mine pit, was lower than that at other monitoring sites. The age of the plant may also have accounted for natural mortality which was greatest at sites on Mt Gibson South.
- There was strong variation in survivorship, health condition and height of *D. masonii* between monitoring sites within a range as well as between groups of monitoring sites. However, the spatial variation was not related to distance from the mine pit.
- The spatial and temporal variation in survivorship, health condition and height of *D. masonii* was not likely to be related to activities at the mine pit. This is because both the temporal variation and small-

scale spatial variation (between monitoring sites) were observed in each of Extension Hill South (adjacent to the mine pit) and Mt Gibson North (at least 2 km from the mine pit).'

A review of the statistical analysis in the Astron Environmental (2014) report by Dr Matthew Williams (Ecoinformatics Unit, DBCA) concluded that the methods of analysis were generally appropriate, however there is insufficient information presented in the report and its appendix to support the conclusion that mining is not indirectly impacting on the habitat of *Darwinia masonii* (M. Williams 2015, pers. comm., 12 August). The analysis is potentially limited by the small subset of data used (i.e. the conclusion may not hold if more of the available data were analysed) and Astron's (2014) conclusions do not appear consistent with the estimated low survival rate of plants near the mining operation (0.24) in comparison with those at mid distance sites (0.45) (Turnbull Kaplan-Meier probability of survival).

Astron (2014) made a number of recommendations to improve the monitoring program, including:

- establish some additional monitoring sites between 25 and 100 m from the mine pit edge
- increase the number of individuals monitored at each site
- consider increasing the efficiency of data collection, i.e. reduce the frequency of monthly monitoring without reducing the quality of data.

In response, MGM added monitoring plots adjacent to the mine pit in 2014 (30 to 60 m from the edge of the pit) which include 84 *D. masonii* plants, and they plan to implement the other recommendations over time (T. Collie 2015, pers. comm.).

4. Implement Fire Management Strategy

MGM and EPHL are required to manage indirect impacts of mining activities, including fire, 'on the populations of *Darwinia masonii* outside the mining footprint' (Condition 8-1, MS 753). Fire is managed under Extension Hill's EMP which includes fire management procedures to minimise the likelihood of an accidental fire ignition and protocols for fire control if there was one (MGM and EHPL 2008b). The Mt Gibson Range is currently managed under a 'no controlled burn' fire management regime. The last bushfire in the Mt Gibson Ranges was in 2005, except for a small two hectare experimental fire in 2009.

5. Manage secondary impacts of mining

MGM and EPHL are required to avoid and manage indirect impacts of mining activities, including dust deposition, fire, weeds, altered hydrology and unauthorised disturbance on the subpopulations of *Darwinia masonii* and other significant flora outside of the mining footprint (Condition 8-1, MS 753). Indirect impacts are currently managed under Extension Hill's EMP (MGM and EHPL 2008b) and *Darwinia masonii* Management Plan (MGM and EHPL 2008a).

Ambient dust monitoring is undertaken by MGM on a monthly basis to determine if there is any correlation between dust deposition on *D. masonii* plants and their respective condition (i.e. plant health), which is reported in Extension Hill's annual environmental reports. Eleven dust deposition gauges are monitored in the locality of the Mt Gibson Ranges. The dust deposition gauges monitor whether or not dust levels exceed the standard: less than 4g/m^2/month of insoluble solids generated by mining activities in the vicinity of *D. masonii* plants (MGM and EHPL 2008a).

6. **Manage inappropriate grazing pressure on *Darwinia masonii***

Impacts from grazing by introduced species (i.e. goats and rabbits) are recorded during the monthly and annual *D. masonii* condition monitoring programme. No significant impacts from grazing have been observed.

7. **Translocation trials**

Some of the habitat requirements and critical parameters required for re-establishing *D. masonii* were determined through BGPA's research including identification of potential translocation sites using a species distribution model, seed dormancy and germination mechanisms, substrate requirements, and the benefit of watering for seedling establishment (BGPA 2010). Ruoss (2013) added an understanding of *D. masonii*'s ecophysiological adaptations and suitability of different substrate types. Some other parameters (e.g. pollination and pollinators, seed viability and dormancy, seed dispersal) which are not well understood may also be critical for the long-term viability of re-establishing subpopulations.

A translocation proposal for a number of translocations of *D. masonii* was developed by MGM (2016). In September 2015, 20 *Darwinia masonii* plants were translocated onto the Extension Hill waste rock landform. These were mostly young plants that had grown in the topsoil stockpiles. Four further translocations were undertaken by MGM in winter/spring 2016 into disturbed areas on the range using plants propagated from genotypes originally collected from either the Extension Hill or Iron Hill areas.

8. **Maintain adequate seed/germplasm collections to ensure material with a broad genetic base is available for translocation and on-going *ex situ* conservation**

Darwinia masonii plants from wild cuttings and cloning have been maintained at Nuts About Natives nursery in Karnup since 2008. BGPA also maintain a small number of genotypes in glasshouses at Kings Park for experimental purposes. Most genotypes are from plants within the mine footprints, with the objective of maintaining this genetic diversity which is to be re-established through translocations. *Darwinia masonii* plants will survive and flower under nursery conditions, however many of the plants have yellow leaf tips and do not grow vigorously (BGPA 2010).

There are a number of seed collections kept in storage at the WA Seed Centre (DBCA), Landcare Services and the Millennium Seedbank at Kew Gardens for long-term storage and some to be used for translocations (BGPA 2010; MGM 2016).

To date most translocations have used plants grown from cuttings or cloning as this is currently the most cost-effective approach to the production of propagules. However, BGPA (2010) recommended further research into seedling production as it appears promising and provides a more genetically diverse source of plants for translocations.

9. **Conduct further surveys and report any new subpopulations of *Darwinia masonii***

The most recent and comprehensive survey, undertaken by Eco Logical Australia (2014), was completed in 2014. The census recorded 20,965 individuals of *D. masonii*, comprising 19,132 mature individuals, 1580 juveniles, 188 seedlings and 65 senescent individuals. This census presented a significant increase in the

recorded abundance of *D. masonii* at the Mt Gibson Ranges over that completed in 2004 (ATA Environmental 2004).

In 2014 a regional survey of nine areas of potential habitat was undertaken by Maia (2014) with no new subpopulations of *D. masonii* located.

10. Promote awareness of *Darwinia masonii*

Extension Hill's mine site environmental induction includes information on the significance of *D. masonii* and the Mt Gibson Ranges in general. There are also photographs and posters of *D. masonii* in the mine site offices.

11. Review ranking of the species and the need for a full Recovery Plan

Darwinia masonii was listed as Vulnerable under IUCN Red List Criteria D2 in 1980.

MGM contracted Globe Environments (2015) to undertake an assessment of whether the proposed Iron Hill mine will impact the conservation status of *D. masonii*. It was concluded by Globe Environments that the proposal would not impact the current conservation status of the species, with climate (principally extended drought) being the most significant future risk factor.

In 2017 the Western Australian Threatened Species Scientific Committee (WATSSC) considered that the impact of the Iron Hill mine would result in continuing decline in numbers of mature individuals of *Darwinia masonii* as well as area of occupancy and extent and quality of habitat, and recommended that the conservation status of the species be changed to Critically Endangered under IUCN Red List criteria B1ab(ii,iii,v). This recommended change was endorsed by the Minister for Environment and published in the Government Gazette WA on 16 January 2018.

As a condition of the Extension Hill mine (MS 753), an Interim Recovery Plan was developed for *Darwinia masonii* in 2008 (DEC 2008b). The conditions of the mine also required the preparation of a full Recovery Plan. MGM and EPHL have been working with DBCA since 2013 to develop this document.

7. Recovery actions

As a requirement of MS 753 for the Extension Hill mine the proponents (MGM and EHPL) were required to prepare and implement a Recovery Plan for *Darwinia masonii*. However, in consultation with DBCA, it was determined that the scope of the plan required to satisfy MS 753 would not be suitable as an approved Recovery Plan for the species. The proponents will therefore prepare and implement a 'Conservation Action Plan' (CAP) to comply with the requirements of Condition 6-3 and 6-5 of MS 753.

Most of the recovery actions in this plan are similar to the actions in the CAP. However where there are differences, this approved recovery plan will override the CAP. The current proponents (MGM and EHPL) have been identified as having responsibility for implementing these recovery actions, however, these responsibilities will transfer to other companies should the proponents change in the future.

The following recovery actions are in order of descending priority, however this should not constrain addressing any of the actions if opportunities arise or funding is available. Estimated costs relating to the recovery actions are summarised in Table 5.

1. Coordinate recovery actions and liaise with stakeholders

DBCA will coordinate the implementation of these recovery actions, with assistance from the Geraldton District Threatened Flora Recovery Team (GDTFRT).

Underlying tenement holders should assist in the coordination of recovery actions for subpopulations within their tenements. MGM and EHPL will implement their CAP and *Darwinia masonii* Offset Plan and will consult with and seek advice from DBCA and other stakeholders where required. An annual progress report on the offset plan, including monitoring data, will be provided to the CEO of the department servicing the EPA and to DBCA (Condition 7-4, MS 1045).

Actions:

- Coordinate recovery actions (DBCA, GDTFRT).
- Liaise with stakeholders (DBCA, MGM & EHPL).
- Implement CAP and offset plans (MGM & EHPL).

Responsibility: DBCA, MGM and EHPL, with assistance from GDTFRT

Timing: ongoing; annually for the report

Commencement date:	On adoption of the Recovery Plan
Completion date:	Life of Recovery Plan

2. Secure long-term protection of habitat

All known habitat for *Darwinia masonii* comprises of banded ironstone formations in the Mt Gibson Ranges, which is prospective for iron ore. The Mt Gibson Ranges coincides with various land tenures of Unallocated Crown Land, a Crown Reserve (managed by the Department of Lands for 'Common') and pastoral leases. The whole of the Mt Gibson Ranges is under mining tenements (*Mining Act 1978* (WA)).

The purpose of this recovery action is to protect a portion of *D. masonii* habitat from threatening processes related to mining for the long-term protection of the species and its habitat *in situ*. This should involve securing an area of habitat in formal conservation estate that is exempt from any exploration or mining activity (e.g. class 'A' nature reserve).

Establishing conservation estate on the Mt Gibson Ranges (such as an 'A' class nature reserve) in order to ensure the long-term conservation of both *D. masonii* and *Lepidosperma gibsonii* has previously been a recommendation of the WATSSC (WA TSSC 2006), the Environmental Protection Authority (EPA 2006) and DBCA. The next stage of establishing this conservation estate would be comprehensive stakeholder consultation.

Actions:

- Continue the process required to create conservation estate on Mt Gibson Ranges incorporating both *D. masonii* and *Lepidosperma gibsonii* subpopulations.

Responsibility: DBCA.

Timing: 2020

Commencement date: Ongoing
Completion date: 2020

3. Maintain seed and germplasm collections

Preservation of propagation material is essential to safeguard against extinction of the species, or its genetic diversity, if wild subpopulations are lost. Some *Darwinia masonii* seed is already collected and stored at the WA Seed Centre and other locations.

There is also a collection of live *D. masonii* germplasm at Nuts About Natives nursery, which has a representation of the genotypes cleared for the mine footprints. This collection should continue to be maintained until viable subpopulations preserving the genetic diversity of the pre-mining *D. masonii* subpopulation have been re-established, or sufficient seed from target subpopulations has been collected and stored. Multiple (>100) genotypes of live plants (BGPA 2010) should be maintained, monitored and supplemented to represent each of the groups cleared during mining activities.

These collections should be made available for on-going *ex situ* conservation including translocation programs. Quantities of seed used from storage in translocation programs may need to be replaced with seed from the same source.

Actions:

- Collate and check records of current *ex situ D. masonii* collections (MGM & EHPL).
- Review adequacy of *ex situ* collections for both long-term conservation and future requirements for translocation programs. Identify what further collections are required (MGM & EHPL, advice from DBCA, 2018).
- Undertake targeted collections of seeds (in late October to early November) to ensure sufficient representation of each subpopulation is in storage (MGM & EHPL, 2015-2019).
- Centralise seed collections for long-term storage into the WA Seed Centre (MGM & EHPL with advice from DBCA, 2018).

Responsibility: MGM and EHPL, with advice from DBCA

Timing: ongoing

Commencement date:	Ongoing
Completion date:	Life of mining activities

4. Develop and implement translocations

Ministerial conditions for the Extension Hill and Iron Hill mines require the proponents to undertake translocations (or regeneration or re-establishment) to offset the direct impacts of the proposals (Conditions 6-2 and 6-3 of MS 753; Conditions 7-1 and 7-2 of MS 1045). This recovery action captures these conditions.

In 2016 MGM and EHPL developed a translocation proposal to translocate 1690 cuttings or seedlings to be planted between 2016 and 2018 (MGM 2016). The translocation proposal details translocation methodology, sites, monitoring and criteria for success.

The objective of these translocations is to establish 'self-sustaining populations' (Conditions 7-2 of MS 1045) of at least 200 plants per subpopulation. The EPA has defined a self-sustaining population as '*a population that is self-perpetuating (able to continue indefinitely) without external assistance*' (Table 3 of MS 1045). The *Darwinia masonii* translocation proposal long-term success criteria are that rates of survival, flower production and seed set and recruitment of a second generation are equivalent to rates of the individuals growing naturally within the nearest subpopulation (MGM 2016). The translocated subpopulation will be considered self-sustaining if it meets these long-term criteria for three consecutive years. It is noted that the timeframes for establishing self-sustaining subpopulation(s) is likely to extend beyond the ten year period of this plan.

Selection of sites should be based on BGPA's (2010) habitat modelling and knowledge gained from the translocation trials that have already been conducted (see Section 1.6.2). The translocation proposal identifies four types of prospective areas: supplementing BGPA's 2005 translocation, disturbed areas within predicted habitat, natural areas within predicted habitat, and areas near or outside of predicted habitat. The translocation proposal also plans for a seeding trial to be undertaken on the Extension Hill waste landform. MS 1045 stipulates '*translocation sites on previously disturbed areas, or areas otherwise agreed to by Parks and Wildlife* (now DBCA)*, on the Mt Gibson Range*' (Condition 7-2.2). Site selection should also take into account

the context of the surrounding ecosystems to ensure the presence of pollen and seed dispersers, especially White-fronted Honeyeaters and seed dispersing ants (BGPA 2010).

The translocation proposal details that plants for the translocations will be sourced from clones of cuttings collected from the wild or that are already in the Nuts About Natives nursery (MGM 2016). Translocations using direct seeding may be done depending on the results of initial trials. Plants sourced from one location will not be translocated to an area within 500 m of a natural subpopulation, unless the stock is from that location. The choice of plants used for these translocations should also aim to maximise genetic diversity, in particular to reintroduce genetic variation that may have been lost with the direct taking of plants for the mining activities.

Based on current genetic information, it is recommended that the separate subpopulation genetic structure should be maintained. Plants sourced from different subpopulations should thus not be mixed with each other and plants should be translocated to areas within the vicinity (i.e. 500 m) of the subpopulation from which their stock was sourced.

Future translocations should consider supplementary watering of plantings as this significantly increased the success rate in BGPA's 2005 translocation trial (BGPA 2010).

Regeneration (e.g. stimulation of recruitment from the seed bank using prescribed fire) or re-establishment (e.g. included in broadscale rehabilitation of mining waste landscapes) are other methods that could be considered to increase plant numbers to offset the direct impacts of the taking of *D. masonii*, as required by ministerial statements. Further research into the likelihood of success of these methods is required prior to implementation.

Actions:

- Establish the translocations planned in the *Darwinia masonii* translocation proposal (MGM and EHPL, 2016-2018).
- Monitor translocations, including previous translocation trials, and supplement them as necessary (MGM and EHPL, ongoing until self-sustaining subpopulations are established).
- Review *D. masonii* genetics to clarify genetic management for translocations (DBCA, 2017).
- Develop and implement translocation proposals for any future translocation or restoration plan requirements (MGM and EHPL, ongoing).
- Identify parameters for assessing the long-term viability of re-established subpopulations of *D. masonii* (MGM & EHPL, ongoing).

Responsibility: MGM, EHPL, DBCA

Timing: Ongoing

Commencement date: 2015
Completion date: Until self-sustaining subpopulations are established

5. Promote awareness of *Darwinia masonii*

An important aspect of conservation is that people must first be aware of what values exist to protect and their significance. The significance of *Darwinia masonii* and the Mt Gibson Ranges in general, and measures to minimise impacts should be communicated to all staff and personnel involved in mining or exploration activities on the Mt Gibson Ranges, including as part of a mine site environmental induction and other communication opportunities.

Actions:

- Promote awareness of the significance of *D. masonii* and the Mt Gibson Ranges in general to mine and exploration personnel through site environmental inductions (MGM & EHPL, life of mining activities).
- On Mt Gibson Ranges mine sites, promote need for protection of *D. masonii* through poster displays or other forms of communication (MGM & EHPL, life of mining activities).

Responsibility: MGM and EHPL

Timing: Ongoing

Commencement date:	Ongoing
Completion date:	Life of mining activities

6. Implement *Darwinia masonii* condition monitoring program

To monitor for any indirect impacts of mining activities, MGM and EHPL have been undertaking regular monitoring of *Darwinia masonii* condition for the Extension Hill mine since 2007 including annual monitoring of established plots across the range, weekly visual inspections of plots closest to the mine and monthly dust deposition monitoring (further details in Section 6). This monitoring will be continued for the life of mining activities (including Extension Hill and Iron Hill mines) in the Mt Gibson Ranges.

The monitoring data from 2007 to 2013 was analysed by Astron (2014), a summary of which is included in Section 6. Astron (2014) found strong variation in *D. masonii* plant survivorship, health condition and height over time and between sites, but no indication of significant impacts from the mining activities.

Astron (2014) made a number of recommendations to improve the monitoring program, including:

- establish some additional monitoring sites between 25 and 100 m from the mine pit edge
- increase the number of individuals monitored at each site
- consider increasing the efficiency of data collection, i.e. reduce the frequency of monthly monitoring without reducing the quality of data.

MGM and EHPL plan to implement the above recommendations and undertake a rolling analysis of the monitoring data collected in the future to improve the monitoring program. The results of the rolling analysis will be used to assess the effectiveness and improve recovery actions using an adaptive management approach. Further detailed analysis of the data should also be undertaken to determine whether variability in plant health is correlated with any environmental factors such as rainfall, fire history or substrate.

Actions:

- Implement the condition monitoring program with continual improvement as required (MGM & EHPL).
- Conduct dust deposition monitoring on a monthly basis using dust deposition gauges around the mines (MGM & EHPL).
- Report upon the condition monitoring program and rolling analysis of data to DBCA on an annual basis (MGM & EHPL).
- Undertake a more detailed analysis of the annual monitoring data to ascertain the cause in the variability in plant health over time and space (MGM & EHPL, DBCA).

Responsibility: MGM, EHPL, DBCA

Timing: Annually (between September – November each year) and monthly as described above

Commencement date:	Ongoing
Completion date:	Life of mining activities

7. Implement fire management strategy

An inappropriate fire regime is a threat to *Darwinia masonii*. MGM and EPHL are required to manage indirect impacts of mining activities, including fire, 'on the populations of *Darwinia masonii* outside the mining footprint' (Condition 8-1, MS 753). Fire is managed under Extension Hill's Environmental Management Plan which includes fire management procedures to minimise the likelihood of an accidental fire ignition and protocols for fire control if there was one (MGM and EHPL 2008b). The Mt Gibson Range is currently managed under a 'no controlled burn' fire management regime.

Darwinia masonii recruits most prolifically following a fire, however the most appropriate fire interval for the species is not known. Most (~73%) *D. masonii* plants recorded by the 2014 census occur within areas burnt in 1969, nearly 50 years ago. The fire interval of *D. masonii* habitat is only known for an area of the 1969 fire that also burnt in 2003 (34 year fire internal), in which 20% of recorded plants now occur.

A prescribed fire to induce recruitment and/or break up the fire ages across the range could be considered sometime in the future, particularly if senescence of adult plants or subpopulation decline is noted. However, this should only be done if DBCA advises that it would be advantageous to the conservation of *D. masonii*. Planning for the fire should go through a detailed planning process, such as a DBCA burn prescription process. Post-fire monitoring of such a burn should be undertaken to record regeneration of *D. masonii*.

Existing post-fire monitoring plots established by BGPA (2010) should continue to be regularly monitored.

Actions:

- Implement the fire management protocols detailed in each Environmental Management Plan prepared for Extension Hill or other mine sites on Mt Gibson Ranges to prevent accidental fire ignition (MGM & EHPL).
- Continue to monitor BGPA (2010) post-fire monitoring plots (MGM & EHPL).
- Consider a future prescribed burn to induce recruitment of *D. masonii* if deemed advantageous to the conservation of the species and monitor the regeneration (DBCA).

Responsibility: MGM and EHPL, DBCA

Timing: ongoing

Commencement date:	Ongoing
Completion date:	Life of mining activities

8. Prevent indirect impacts of mining activities

MGM and EPHL are required to avoid and manage indirect impacts of mining activities, including dust deposition, fire, weeds, altered hydrology and unauthorised disturbance on the subpopulations of *Darwinia masonii* and other significant flora outside of the mining footprint (Condition 8-1, MS 753). Indirect impacts are currently managed under Extension Hill's EMP (MGM and EHPL 2008b).

Action:

- Implement Extension Hill's (or another mine site on Mt Gibson Range) EMP to prevent indirect impacts of the mining activities (MGM & EHPL).
- If mining is found to have an indirect impact on *D. masonii* (Action 6), undertake mitigation measures to prevent further impacts (MGM & EHPL).
- If an infestation is identified of an invasive weed species that could impact on *D. masonii*, undertake weed control to eradicate the weed (MGM & EHPL).

Responsibility: MGM and EHPL

Timing: ongoing

Commencement date:	Ongoing
Completion date:	Life of mining activities

9. Protect plants from herbivory

Grazing is not currently having a significant impact on *Darwinia masonii,* however rabbits and goats are present in the Mt Gibson Ranges and their densities may increase in the future. Therefore grazing is a potential future threat to *D. masonii* and the integrity of its habitat.

The annual monitoring of *D. masonii* condition (Action 6) includes recording any impacts of grazing observed. If grazing pressure begins to impact *D. masonii*, either directly or through damage to associated habitat, MGM and EHPL will need to undertake feral animal control on the mining tenements either through fencing or feral animal control (pastoral consent required). After the life of mining ends in the Mt Gibson Ranges, land managers will be responsible for feral animal control.

Action:

- Continue to review grazing effects in annual *D. masonii* condition monitoring data (Action 6) (MGM & EHPL).
- If grazing is having significant adverse impacts on *D. masonii* or its habitat, implement an appropriate feral animal control program in consultation with relevant stakeholders.

Responsibility: MGM and EHPL (on mining tenure); DBCA and other land managers (non-mining tenure)

Timing: Annually

Commencement date:	Ongoing
Completion date:	Life of Recovery Plan

10. Continue undertaking research to assist recovery

MGM and EHPL are required to prepare and implement a *Darwinia masonii* Research Plan, which they are also required to review and revise when directed by the EPA (Conditions 6-1, 6-4, 6-7 and 6-8 of MS 753).

To address the above conditions, BGPA (2008) developed a Conservation and Restoration Research Proposal and undertook a significant research project into the ecology of *D. masonii* between 2007 and 2010. Following this project, BGPA (2010) recommended further research in a number of areas, including:

- finalise and publish the Barrett & Krauss (in prep.) manuscript containing the results and conclusions of the latest genetic assessment
- map soil or regolith data for the region to refine the distribution model to improve understanding and predictions of the habitat and restoration requirements for *D. masonii*
- identify the seed-eating moth species and survey for its occurrence on co-occurring species and related *Darwinia* species
- annual collection of a sample of (>10) infructescences of *D. masonii* from each major subpopulation to assess rates of seed predation and seed fill
- continue BGPA's (2010) seed burial and retrieval trials
- further research into seedling production under laboratory, glasshouse or field conditions to consider the feasibility of providing a genetically diverse and numerous source of restoration plants
- review the role of birds in *D. masonii* pollination.

Actions:

- Prioritise the above research actions and implement according to resourcing and budget considerations over a five year period.
- Review and revise the *Darwinia masonii* Research Plan as required.

Responsibility: MGM and EHPL

Timing: 2018-2022.

Commencement date:	Commencement of the Recovery Plan
Completion date:	Life of Recovery Plan

11. Monitor subpopulations

All subpopulations of *Darwinia masonii* will be monitored for the purpose of conducting a regular census of *D. masonii* in the wild. This differs from plant condition monitoring, which focuses on a subset of plants and regularly monitors the condition in that subset (Action 6). This is a comprehensive form of monitoring that will occur once every five years or more frequently if the condition monitoring program indicates that the subpopulation or health of mature plants is declining outside of the stable range. The results of this subpopulation monitoring will be used to assess the effectiveness of, and improve, the recovery actions.

Darwinia masonii occurs in 10 TPFL subpopulations. The boundaries of some of the subpopulations are interpreted differently by different stakeholders as some of the TPFL subpopulations are geographically closer together (< 500 m) than DBCA's guidelines allow (DEC 2012) but are considered to be separate subpopulations as they form discrete groups on and around different ridgetops. However, records from the 2014 census indicate that there may be physical connections between some subpopulations. Therefore, the TPFL subpopulation boundaries should be reviewed in conjunction with the results of unpublished genetic work that indicates genetic distinction between the current TPFL subpopulations (M. Barrett 2013, pers. comm.).

Action:

- Monitor the entire population once every five years; or once every three years if the populations or health of mature plants is declining outside of the stable population range (MGM & EHPL).
- Provide report on the monitoring undertaken to DBCA (MGM & EHPL).
- Review the boundaries of the TPFL subpopulations (DBCA, 2018).

Responsibility: MGM and EHPL

Timing: 2019 and ongoing at rate specified

Commencement date:	On adoption of the Recovery Plan
Completion date:	Life of Recovery Plan

12. Report any new occurrences of *Darwinia masonii*

If further subpopulations of *Darwinia masonii* are found, their details, in accordance with the TPFL Form, should be reported to DBCA.

Action:

- Report opportunistic observation of any new plant or subpopulation record to DBCA.

Responsibility: MGM and EHPL

Timing: Ongoing

Commencement date:	ongoing
Completion date:	Life of Recovery Plan

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

This plan will be reviewed every 10 years or as required if there is a significant change in the species' subpopulations or threats, and the need for further actions assessed.

Actions:

- Review and revise this Recovery Plan.

Responsibility: DBCA with assistance from MGM, EHPL and GDTFRT

Timing: 2028

Commencement date:	2028
Completion date:	Life of Recovery Plan

8. International obligations

This plan is fully consistent with the aims and recommendations of the Convention on Biological Diversity, ratified by Australia in June 1993, and will assist in implementing Australia's responsibilities under that Convention. The species is not listed under Appendix II in the United Nations Environment Program World Conservation Monitoring Centre (UNEP-WCMC) Convention on International Trade in Endangered Species (CITES), and this plan does not affect Australia's obligations under any other international agreements.

9. Guide for decision makers

Any proposed land use or action that may significantly impact on *Darwinia masonii* or its habitat may require environmental impact assessment under the Western Australian *Environmental Protection Act 1986* and/or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Any person proposing to undertake actions which may have a significant impact on any listed threatened species or ecological community should refer the action to the Commonwealth Minister for the Environment. The Minister will then determine whether the action requires EPBC Act assessment and approval.

Actions which could have a significant impact on *D. masonii* include those that may result in any of the following occurring to habitat that is important for the survival of the species:

- disturbance of the soil or native vegetation
- direct removal of *D. masonii* or native vegetation habitat
- inadvertent disturbance of habitat through increase in dust, changed microclimate or changed hydrology
- increase in fire frequency or likelihood of bushfire
- increase the likelihood of grazing impact by feral and domestic herbivores
- fragmentation or reduction in connectivity of habitat
- disturbance of or change to the pollinator and/or seed disperser community that services *D. masonii*
- weed invasion.

10. Interest groups, social and economic impacts and benefits

10.1 Affected interests

The known subpopulations of *Darwinia masonii* occur across a variety of land tenures including pastoral leases, Crown Reserve (Reserve 17367) and Unallocated Crown Land, all of which are covered by active mining leases. Based on the current distribution of *D. masonii*, interests potentially affected by, or involved in the implementation of this plan, include mining proponents (MGM, EHPL), Pindiddy Aboriginal Corporation (Ninghan Station), Australian Wildlife Conservancy (Mt Gibson Station), the Badimia People, Shire of Perenjori and DBCA.

Implementation of this recovery plan may potentially result in impediments or restrictions on the use of land that is important habitat for *D. masonii*. Landholders and land management agencies may be affected through statutory planning and approval processes when seeking to alter the landscape or undertake actions that may impact on *D. masonii*.

Prior to undertaking recovery actions in this plan, permission will be obtained from relevant managers and/ or those with entitlements to the relevant lands.

10.2 Role and interest of Aboriginal groups

The Badimia People (WC96/98) have expressed an interest in the environment and natural history of the Mt Gibson Ranges through agreements with MGM and EHPL. Their Native Title claim was dismissed in 2015 due to 'connection issues'. However there are a number of registered ethnographic and/or archaeological sites within the habitat of *Darwinia masonii* which are of cultural significance. The Aboriginal Heritage Sites Register maintained by the Department of Planning, Lands and Heritage and the works of Tehnas (2010) provide information on the existence and status of these Aboriginal heritage sites as well as some regional ethnography.

Input and involvement would be welcome from any Aboriginal groups that have an active interest in areas where *D. masonii* occurs. MGM and EHPL have undertaken consultation with claimant groups through stakeholder meetings since 2008 and will continue to consult in relation to the company's activities in the Mt Gibson Ranges area.

10.3 Social and economic impacts and benefits

The implementation of this recovery plan could potentially have social or economic impacts, because habitat that is important to the survival of *Darwinia masonii* occurs on BIF that is under live mining leases and could be prospective for iron ore. Proponents of land uses that could impact *D. masonii* on Mount Gibson ranges will need to demonstrate through statutory processes that the land uses will have no significant impact on *D. masonii* or that any impacts can be adequately mitigated. Such requirements would be in place irrespective

of this plan, and this plan will provide guidance for decision-makers and for the implementation of mitigation measures.

Mining of iron ore is already being undertaken in areas of important *D. masonii* habitat on Extension Hill and Iron Hill. Consequently, the proponents, MGM and EHPL, are implementing some of the recovery actions in the plan as required by the relevant ministerial approvals. This includes significant research and management of *D. masonii*.

11. Implementation and evaluation

The coordination and implementation of this recovery plan will be overseen by DBCA. MGM and EHPL will implement a number of the recovery actions as required by the relevant ministerial approvals for mining in the Mt Gibson Ranges.

The plan will be implemented for a minimum of 10 years from the date of its approval, or until it is replaced by another approved plan. DBCA, in consultation with relevant stakeholders, will review and evaluate the performance of this recovery plan as required or after 10 years. The recovery plan may be revised in light of these reviews or as new information or research findings become available.

The estimated cost of implementing this recovery plan is summarised in Table 5. These estimated costs do not include the operational costs associated with MGM and EHPL implementing recovery actions that reduce threats from mining activities or associated restoration.

Table 5: Summary of recovery actions and indicative costs over five years

Recovery action	Responsibility	Estimated costs ($)				
		2018	2019	2020	2021	2022
1 Coordinate recovery actions and liaise with stakeholders						
Coordinate recovery actions, liaise with stakeholders and annual progress report.	DBCA & GDTFRT	*MGCP funding	*MGCP funding			
Implement the CAP and offset plans	MGM & EHPL	Operation budget	Operation budget	Operation budget	Operation budget	Operation budget
2 Secure long-term protection of habitat						
Continue process required to create conservation estate on Mt Gibson Ranges, or alternative protection strategies	DBCA	Operation budget	Operation budget	Operation budget	Operation budget	Operation budget
3 Maintain and use seed/germplasm collections to ensure material with a broad genetic base is available for conservation						
Collate and annually check records of current *ex situ D. masonii* collections	MGM & EHPL	Operation budget	Operation budget	Operation budget	Operation budget	Operation budget
Review adequacy of *ex situ* collections and identify what further collections are required.	MGM & EHPL	$2,000				
Undertake targeted collection of seeds to ensure sufficient representation of each subpopulation is in storage.	MGM & EHPL	7,500	7,500		7,500 (if req'd)	
Centralise seed collections for long-term storage into the WA Seed Centre.	MGM & EHPL		Operation budgets			
4 Develop and implement translocations						
Establish the translocations planned in the translocation proposal (MGM 2016)	MGM & EHPL	10,000	10,000	10,000	10,000	10,000
Monitor translocations and supplement them as necessary.	MGM & EHPL	15,000	15,000	15,000	15,000	15,000

Recovery action	Responsibility	Estimated costs ($)				
		2018	2019	2020	2021	2022
Review *D. masonii* genetics to clarify genetic management for translocations	DBCA	100,000				
Develop translocation proposals for any future translocations	MGM & EHPL	not budgeted				
Identify parameters for assessing the long-term viability of re-established subpopulations of *D. masonii*.	MGM & EHPL	10,000	10,000			
5 Promote awareness of *Darwinia masonii*						
Promote awareness of *D. masonii* to mine site personnel through site environmental inductions.	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
Promote need for protection through poster displays and other forms of communication on the mine site	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
6 Implement *Darwinia masonii* condition monitoring program						
Implement the condition monitoring program for *Darwinia masonii* based on continual improvement.	MGM & EHPL	25,000	25,000	25,000	25,000	25,000
Conduct dust deposition monitoring on a monthly basis using dust deposition gauges.	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
Report upon the condition monitoring program to DBCA annually	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
Undertake more detailed analysis of annual monitoring data to ascertain cause of variability over time and space.	MGM & EHPL, DBCA	*MGCP funding	*MGCP funding			
7 Implement fire management strategy						
Implement fire management protocols in Environmental Management Plans	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
Continue to monitor BGPA's post-fire monitoring plots	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
Consider a future prescribed burn	DBCA	not budgeted				
8 Prevent indirect impacts of mining activities						
Implement Environmental Management Plans to prevent indirect impacts	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
If indirect impact is found, mitigation measures need to be undertaken.	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
Undertake weed control to eradicate week if an infestation is found.	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
9 Protect plants from herbivory						
Continue to review grazing effects in annual *D. masonii* condition monitoring data.	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
If grazing is having an adverse implement an appropriate feral animal control program in consultation with relevant stakeholders.	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
10 Continue undertaking research to assist recovery						
Prioritise research and implement according to resourcing and budgeting	MGM & EHPL	20,000	20,000	20,000		
Review and revise Research Plan as required	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
11 Monitor subpopulations						
Monitor the entire population once every 5 years; otherwise at a rate of every 3 years, and provide report to DBCA.	MGM & EHPL		110,000			
Review the boundaries of the TPFL subpopulations	DBCA	*MGCP funding				
12 Report any new occurrences of *Darwinia masonii*						
Report opportunistic observation of any new plant or subpopulation record to DBCA.	MGM & EHPL	Operation budgets	Operation budgets	Operation budgets	Operation budgets	Operation budgets
13 Review this recovery plan						
Review and revise this Recovery Plan.	DBCA					

*MGCP – DBCA is funded by MGM & EHPL at $110,000 p.a. through offset 4 of MS 753 for the life of Extension Hill Mine to employ staff to assist with the development and implementation of the recovery plan under the Mt Gibson Conservation Project.

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Appendix 1 – Threat assessment

Criteria and Rating Method For Threat and Risk Assessments

Threat Assessment

Analysis and rating of the threatening processes impacting *Darwinia masonii* was completed with the Open Standards of the Practice of Conservation guidelines (CMP 2013). This analysis and ranking was completed by DBCA staff Anthony Desmond, Rowan Dawson, Alanna Chant and Kiera Foster, based on best available knowledge and the current understanding of the impacts of individual threatening processes on the species.

The ratings are based on the following three criteria (WWF 2007):

Box 2. Criteria for Threat Ranking Using the Absolute System

Scope – The proportion of the target that can reasonably be expected to be affected by the threat within ten years, given the continuation of current circumstances and trends. For ecosystems and ecological communities, measured as the proportion of the target's occurrence. For species, measured as the proportion of the target's population.

- **4 = Very High:** The threat is likely to be pervasive in its scope, affecting the target across all or most (71-100%) of its occurrence/population.
- **3 = High:** The threat is likely to be widespread in its scope, affecting the target across much (31–70%) of its occurrence/population.
- **2 = Medium:** The threat is likely to be restricted in its scope, affecting the target across some (11–30%) of its occurrence/population.
- **1 = Low:** The threat is likely to be very narrow in its scope, affecting the target across a small proportion (1-10%) of its occurrence/population.

Severity – Within the scope, the level of damage to the target from the threat that can reasonably be expected given the continuation of current circumstances and trends. For ecosystems and ecological communities, typically measured as the degree of destruction or degradation of the target within the scope. For species, usually measured as the degree of reduction of the target population within the scope.

- **4 = Very High:** Within the scope, the threat is likely to destroy or eliminate the target, or reduce its population by 71-100% within ten years or three generations.
- **3 = High:** Within the scope, the threat is likely to seriously degrade/reduce the target or reduce its population by 31-70% within ten years or three generations.
- **2 = Medium:** Within the scope, the threat is likely to moderately degrade/reduce the target or reduce its population by 11-30% within ten years or three generations.
- **1 = Low:** Within the scope, the threat is likely to only slightly degrade/reduce the target or reduce its population by 1-10% within ten years or three generations.

Irreversibility (Permanence) – the degree to which the effects of a threat can be reversed and the target affected by the threat restored. It is assessed for the impact of the threat on the target, not the threat itself.

- **4 = Very High:** The effects of the threat cannot be reversed, it is very unlikely the target can be restored, and/or it would take more than 100 years to achieve this (e.g., wetlands converted to a shopping centre).
- **3 = High:** The effects of the threat can technically be reversed and the target restored, but it is not practically affordable and/or it would take 21–100 years to achieve this (e.g., wetland converted to agriculture).
- **2 = Medium**: The effects of the threat can be reversed and the target restored with a reasonable commitment of resources and/or within 6–20 years (e.g., ditching and draining of wetland)
- **1 = Low:** The effects of the threat are easily reversible and the target can be easily restored at a relatively low cost and/or within 0–5 years (e.g., off-road vehicles trespassing in wetland).

The assessors calculated the risk ratings using the below rules to first combine the Scope and Severity variables to get a Threat Magnitude, which is then combined with Irreversibility to get the ratings.

Threat magnitude

		Scope			
		Very high	**High**	**Medium**	**Low**
Severity	**Very High**	Very High	High	Medium	Low
	High	High	High	Medium	Low
	Medium	Medium	Medium	Medium	Low
	Low	Low	Low	Low	Low

Risk rating

		Irreversibility			
		Very high	**High**	**Medium**	**Low**
Magnitude	**Very High**	Very High	Very High	High	Medium
	High	High	High	Medium	Low
	Medium	Medium	Medium	Low	Low
	Low	Low	Low	Low	Low