**MOUNT GIBSON MINING LIMITED**

# OFFSETS MANAGEMENT PLAN

**Version 4**

**Date of Revision: 18 May 2021**

Mount Gibson Mining Limited
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## Document Control

| | |
|---|---|
| **Project** | Iron Hill Deposits Project |
| **Title** | Offsets Management Plan |

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# Executive Summary

The Offsets Management Plan (**this Plan**) meets the requirements of the Western Australian Environmental Offsets Policy (Western Australian Government, 2011) and the Western Australian Environmental Offsets Guidelines (Western Australian Government, 2014), and builds on knowledge research outcomes arising from the Mt Gibson Iron Ore Mine and Infrastructure Project environmental offsets package (Ministerial Statement Number 753).

The environmental offsets in this Plan apply to the Iron Hill Deposits Mining Project (Assessment Number 2034; EPBC 2015/7514) which extends the life of hematite mining on the Mt Gibson Ranges by two to three years.

Extensive knowledge was gained from the original offsets package after the issue of Ministerial Statement Number 753 (MS 753) (with a value of approx. $2.7M over nine years between 2007 and 2016); initially, involving an extensive research program before the commencement of mining, as well as development and implementation of Plans for the Rare Flora species, *Darwinia masonii* and *Lepidosperma gibsonii*.

Following the application of avoidance, minimisation and mitigation measures in the formal Environmental Impact Assessment of the Iron Hill Deposits Mining Project (the Project), and through a stakeholder consultation process, MGM estimated the following significant residual impacts:

- The proposed disturbance footprint may have a cumulative impact on up to 22% of the *Darwinia masonii* population as approximately 6% (approx. 1,327 plants) occur within the Iron Hill Deposits Development Envelope.
- *Lepidosperma gibsonii* occurs on the Mt Gibson Ranges tenements and beyond. The Project may impact less than 2% (approx. 863 plants) of the known confirmed records with a projected future cumulative impact of approximately 18% resulting from the Project and existing mining operations (approved under MS 753) at the Mt Gibson Ranges.

The following key environmental offsets are addressed by this plan:

- OFFSET D1 - Re-establishment of at least 1327 *Darwinia masonii* as a result of implementing the proposal across the Mt Gibson Ranges.
- OFFSET L1 - Re-establishment of at least 863 *Lepidosperma gibsonii* as a result of implementing the proposal across the Mt Gibson Ranges.
- OFFSET L2 -Research program to confirm the taxonomic identity, and subsequently the numbers of *Lepidosperma gibsonii* plants on the surrounding plains of the Mt Gibson Range, to the west of the Great Northern Highway (Appendix F).

This Plan describes:

- the implementation of offsets through translocation for the two rare species through the development of actions, milestones and timelines (Section 3),
- consideration of risks to the successful implementation of the respective offsets and mitigation actions are proposed to reduce the highest risks to as low as possible (Appendix D),
- completion criteria for assessing attainment of objectives and targets are described in Section 4; and
- monitoring and reporting (Section 5 and 6, respectively).

Offsets D1 and L1 are also enabled by approved Translocation Proposals endorsed by the delegate at Department of Parks & Wildlife (now DBCA) under the former *Wildlife Conservation Act*.

# Abbreviations

| | |
|---|---|
| BGPA | Botanic Gardens and Parks Authority |
| BIF | Banded Ironstone Formation |
| DBCA | Department of Biodiversity Conservation and Attractions |
| DEC | Department of Environment and Conservation |
| DER | Department of Environmental Regulation |
| DWER | Department of Water and Environmental Regulation |
| DMP | Department of Mines and Petroleum |
| DotEE | Department of the Environment and Energy (Commonwealth) |
| Parks & Wildlife | Department of Parks and Wildlife |
| DRF | Declared Rare Flora |
| EIA | Environmental Impact Assessment |
| EHPL | Extension Hill Pty Ltd |
| EMP | Environmental Management Plan |
| EP Act | *Environmental Protection Act 1986* |
| EPA | Environmental Protection Authority |
| EPBC Act | *Environment Protection & Biodiversity Conservation Act 1999* |
| IRP | Interim Recovery Plan |
| MGM | Mount Gibson Mining Limited |
| MS753<br>MS1045 | Ministerial Statement Number 753<br>Ministerial Statement Number 1045 |
| OEPA | Office of the Environmental Protection Authority |
| PEC | Mt Gibson Vegetation Complexes Priority 1 Ecological Community |
| PER | Public Environmental Review |
| R&D | Research and Development |
| RISM | Residual Impact Significance Model |
| the Guidelines | Environmental Offsets Guidelines (Western Australian Government2014) |
| the Project | Iron Hill Deposit Mining Project (Assessment Number 2034) |
| this Plan | Offsets Management Plan |
| TPFL | Threatened and Priority Flora Population |

# CONTENTS

**1 INTRODUCTION ..... 5**
*1.1 Initial R&D ..... 5*
*1.2 The Iron Hill Deposits project ..... 5*
**2 SCOPE OF THIS PLAN ..... 6**
**3 OFFSETS ..... 9**
*3.1 Darwinia masonii translocations ..... 9*
*3.1.1 Matters to consider for identifying suitable D. masonii translocation sites ..... 9*
*3.1.2 Sourcing plant materials from Iron Hill and Iron Hill South ..... 10*
*3.1.3 Matters to consider to use plant materials for translocations ..... 10*
*3.1.4 Protection measures for fire, mining and exploration ..... 11*
*3.2 Lepidosperma gibsonii translocations ..... 13*
*3.2.1 Matters to consider for identifying suitable L. gibsonii translocation sites ..... 15*
*3.2.2 Sourcing plant materials from Iron Hill ..... 15*
*3.2.3 Matters to consider to use plant materials for translocations ..... 17*
**4 COMPLETION CRITERIA AND ADAPTIVE MANAGEMENT ..... 20**
*4.1 Offset D1: Darwinia masonii translocation program ..... 20*
*4.2 Offset L1: Translocation of Lepidosperma gibsonii plants ..... 22*
*4.3 Offset L2: Lepidosperma gibsonii research ..... 24*
**5 MONITORING ..... 25**
*5.1 Offset D1 and L1 D. masonii and L. gibsonii translocations ..... 25*
*5.2 Offset L2 L. gibsonii research ..... 26*
**6 REPORTING ..... 27**
**7 REFERENCES ..... 28**

## List of Figures

Figure 1: Juvenile D. *masonii* plants held at Nuts About Natives Nursey in early 2016 ..... 10
Figure 2: Examples of suitable translocation sites at Mt Gibson Range ..... 11
Figure 3: Potential, current and preferred translocation sites (refer Appendices A2 and B2 for details) ..... 14
Figure 4: Potential and preferred translocation sites for L. gibsonii (refer to Appendices A2 and B2 for details) ..... 16

## List of Tables

Table 1: Requirements of MS1045 conditions for *Darwinia masonii* translocation(s) ..... 7
Table 2: Requirements of MS1045 conditions for Lepidosperma gibsonii translocation(s) ..... 8
Table 3: Key milestones for D. *masonii* offsets ..... 9
Table 4: Nominal timeframe for D. *masonii* translocation activities .....12
Table 5: Key milestone for L. *gibsonii* offsets .....13
Table 6: Nominal timeline for L. *gibsonii* translocation activities.....18

## List of Appendices

Appendix A *Darwinia masonii* Translocation Proposal
Appendix B *Darwinia masonii* Translocation Site Selection Matrix and Site Location
Appendix C: *Lepidosperma gibsonii* Translocation Proposal
Appendix D: *Lepidosperma gibsonii* Translocation Site Selection Matrix
Appendix E: Correspondence with Parks and Wildlife
Appendix F: Risk Assessment
Appendix G: Background Information and Data for Translocation Sites
Appendix H: *Lepidosperma gibsonii* research plan
Appendix I: Progress report on 2019 Translocation Results

# 1 INTRODUCTION

## 1.1 Initial R&D

Mount Gibson Mining Limited (MGM) has been mining at Extension Hill at the Mt Gibson Ranges since 2010. Prior to this time, MGM and Extension Hill Pty Ltd (EHPL) went through an extensive formal Environmental Impact Assessment (EIA) via Part IV of the Environmental Protection Act 1986 (WA; EP Act). An offsets package was developed and accepted with the issuing of MS 753, and has since been implemented.

Conditions 6, 7, and 16 of MS753 required the implementation of an offsets program involving extensive research of the listed species, *Darwinia masonii* and Lepidosperma gibsonii, and implementation of Recovery Plans. That offsets program was developed by various contributors in partnership with the Department of Environment and Conservation (DEC; Formerly Department of Parks and Wildlife, Parks & Wildlife and currently the Department of Biodiversity Conservation and Attractions, DBCA) and the Botanic Gardens and Parks Authority (BGPA; currently DBCA).

An extensive research program (funded by MGM and EHPL) was initiated in 2007 by BGPA and completed in 2010 (BGPA, 2010). That program focussed on seven broad research aspects:

1. Conservation genetics: Population structure, comparison with other species, phylogeny and clonality.
2. Population demography: Fire, demography, tools for monitoring plant demographic changes.
3. Breeding/recruitment biology: Seed research, seed production, soil seed bank, phenology, genetic analysis of breeding systems and dispersal.
4. Population Viability Analysis: Modelling of population persistence.
5. Environmental interactions and plant health: Biotic and abiotic associations, habitat requirement assessment, ecophysiology, impacts of associations on plant health, and tools to monitor plant health.
6. Restoration and translocation: Reconstruction of habitat, propagation, translocations, and tools to monitor rehabilitation, dust, and water table lowering.
7. Ex-situ conservation propagation for long-term seed storage, and cryostorage. The final research report was presented to proponents in 2010[1]

## 1.2 The Iron Hill Deposits project

Separately, MGM referred the Iron Hill Deposits mining project (the Project) under Part IV of the EP Act (Assessment Number 2034) and received Ministerial Approval (Ministerial Statement 1045, MS1045) in December 2016. The Iron Hill Deposits project extends the mining of hematite on the Mt Gibson Ranges by approximately two to three years.

By virtue of the original cloning, culturing and translocation trials initially conducted by BGPA and then expanded by MGM, direct offsets were proposed and accepted by EPA as part of its recommendation for Ministerial approval in 2016.

[1] Botanic Garden and Parks Authority (2010). *Darwinia masonii and Lepidosperma gibsonii Conservation and Restoration Research: An integrated research program into the ex situ and in situ conservation, restoration and translocation requirements of Darwinia masonii and Lepidosperma gibsonii*. Report to sponsors, 2010.

# 2 Scope of this Plan

This Offsets Management Plan (the Plan) applies only to the direct offsets required for the Iron Hill Deposits Project (the Project) It addresses the requirements of the Western Australian Environmental Offsets Policy (Western Australian Government, 2011) and the Western Australian Environmental Offsets Guidelines (Western Australian Government, 2014; the Guidelines), and builds on knowledge outcomes from the Mt Gibson Iron Ore Mine and Infrastructure Project environmental offsets package (MS753).

This Plan applies to the offset requirements of MS1045, which specifies the following:

*7 -1 The proponent shall undertake an offset, as outlined in condition 7-2 and 7-8, with the objective to counterbalance the significant residual impact on:*

*(1) 1,327 plants of Darwinia masonii; and*

*(2) 863 plants of Lepidosperma gibsonii, as a result of the implementation of the proposal.*

*7-2 Within six months of issue of this Statement, or as otherwise agreed in writing by the CEO, the proponent shall prepare, in consultation with Parks and Wildlife and submit a Darwinia masonii Offset Plan to the CEO.*

*The objective of the Plan is to ensure a self-sustaining population of at least 1,327 mature individuals of Darwinia masonii.*

*7-8 Within six months of issue of this Statement, or as otherwise agreed in writing by the CEO, the proponent shall prepare, in consultation with Parks and Wildlife and submit a Lepidosperma gibsonii Offset Plan to the CEO.*

*The objectives of the Lepidosperma gibsonii Offset Plan are to:*

- *confirm the distribution of Lepidosperma gibsonii; and*
- *ensure a self-sustaining population of at least 863 mature individuals of Lepidosperma gibsonii.*

The requirement to confirm the distribution of Lepidosperma gibsonii is addressed in the *Lepidosperma gibsonii* Research Plan included as Appendix F to this Plan.

The research required by MS753 as an original offset has been completed by BGPA (2010). That research also supported certain recovery actions as per the species Interim Recovery Plans. This Plan builds on the previously completed research (BGPA 2010) to be able to directly offset the residual impacts of the Iron Hill Proposal, whilst recovery actions required by MS753 continue as per species Recovery Plans. This Plan has not been developed nor will it be implemented to meet the requirements of MS753.

MS1045 provides a quantified target and criteria which need to be met. Appendices A2 and B2, and Figures 3 and 4 show the anticipated translocation sites for the green stock sourced from Iron Hill populations. The completion criteria that must be achieved to satisfy the objectives and targets of this Plan are described in Section 4.

While the details provided within Appendices A1 and B1 may also be applied to recovery actions undertaken for purposes related to MS753, this Plan only describes those sites which have been approved by Parks & Wildlife as per the approved translocation proposals for meeting the offset requirements of MS1045. The translocation sites listed and described by Appendices A2 and B2 are those related to the offset requirements of MS1045. Correspondence provided within Appendix C demonstrates approval of those translocation sites by Parks & Wildlife for the purpose of returning

specimens as wildstock and as consultation with Parks & Wildlife for the adoption of those sites to meet Offset requirements of MS1045 and the content of this plan.

To summarise, this Plan addresses the criteria as outlined by conditions of MS1045 and how this Plan addresses those conditions is outlined by Tables 1 and 2.

**Table 1: Requirements of MS1045 conditions for *Darwinia masonii* translocation(s)**

| Condition # | Requirement | Section in thePlan |
|---|---|---|
| 7-2 (1) | *Describe the plant material to be used for translocation, topromote the viability of the species, on advice of Parks andWildlife;* | Section 3.1.2Appendix A1 |
| 7-2 (2) | *Identify suitable translocation sites on previously disturbedareas, or areas otherwise agreed to by Parks and Wildlife,on the Mt Gibson Range.* | Section 3.1.1<br>Figure 3 Appendix A2 |
| 7-2 (3) | *Identify the number of mature plants that each translocation site could support.* | Appendix A2<br>Appendix E |
| 7-2 (4) | *Describe the ongoing protection measures afforded to thetranslocated plants from threats including, but not limited to, fire and future exploration and mining* | Section 3.1.4Appendix D |
| 7-2 (5) | *Identify completion criteria to demonstrate that the translocated plants have established, are reproducing andthere is a soil-stored seedbank;* | Section 4.1 |
| 7-2 (6) | *Identify timeframes and responsibilities for its implementation.* | Section 3.1 |
| 7-2 (7) | *identify reporting procedures, including the content, format, timing and frequency for the reporting of monitoring data against the completion criteria, in accordance with condition 7-3; and* | Section 5.1<br>Section 6 |
| 7-2 (8) | *identify management and contingency measures shouldcompletion criteria not be met.* | Section 4.1 |
| 7-4 | *The proponent shall monitor the success of implementation of the Darwinia masonii Offset Plan required by condition 7-2 and provide a written report, including monitoring data, to the CEO and Parks and Wildlife every twelve (12) months on the progress of this project until completion criteria have been met. The first report must be submitted within fifteen (15) months of receiving the notice under condition 7-3.* | Section 6 Appendix G |

**Table 2: Requirements of MS1045 conditions for *Lepidosperma* gibsonii translocation(s)**

| Condition # | Requirement | Section in OMP |
|---|---|---|
| 7-8 (2) | Describe the plant material to be used for translocation, to promote the viability of the species, on advice of Parks and Wildlife; | Section 3.2.2<br>Appendix B1 |
| 7-8 (3) | Identify suitable translocation sites on previously disturbed areas[2]. | Section 3.2.1<br>Appendix B2 |
| 7-8 (4) | Identify the number of mature plants that each translocation site could support. | Appendix B2 |
| 7-8 (5) | Describe the ongoing protection measures afforded to the translocated plants from threats including, but not limited to, fire, grazing and future exploration and mining. | Section 3.2.4<br>Appendix D |
| 7-8 (6) | Identify completion criteria to demonstrate that the translocated plants have established and are reproducing. | Section 4.1<br>Appendix B1 |
| 7-8 (7) | Identify timeframes and responsibilities for implementation. | Section 4.2 |
| 7-8 (8) | Identify reporting procedures, including the content, format, timing and frequency for the reporting of monitoring data against the completion criteria, in accordance with condition 7-9; and | Section 5.1<br>Section 6<br>Appendix B1 |
| 7-8 (9) | Identify management and contingency measures should completion criteria not be met. | Section 4.2 |
| 7-10 | The proponent shall monitor the success of implementation of the *Lepidosperma gibsonii* Offset Plan required by condition 7-8 and provide a written report, including monitoring data, to the CEO and Parks and Wildlife every twelve months on the progress of this project until completion criteria have been met. The first report must be submitted within fifteen (15) months of receiving the notice under condition 7-9. | Section 6<br>Appendix G |

[2] For the purpose of this Plan, 'previously disturbed' is defined as an area which has evidence of being disturbed prior to use of the area for translocations (may include but not be limited to exploration, fire or other processes which disturbed the cover of native vegetation) and / or provides adequate open ground for the translocation and irrigation of plants without requirement to clear existing native vegetation.

# 3 Offsets

## 3.1 *Darwinia masonii* translocations

The following is a summary of the environmental offset:

**OFFSET D1** ***Darwinia masonii* Translocation Program**

**(direct action)** Re-establishment of at least 1,327 *Darwinia masonii* as a result of implementing the proposal across the Mt Gibson Ranges (implementation by MGM).

**Table 3: Key milestones for D. *masonii* offsets**

| Offset | Milestone | Timeframe | Responsibility |
|---|---|---|---|
| Offset D1 | Implementation of D. *masonii* Translocation Proposal (refer to Appendices A1 and A2). | 2016-2021 | MGM |

### 3.1.1 Matters to consider for identifying suitable D. *masonii* translocation sites

The suitability of the translocation sites within the Mt Gibson Ranges has been determined upon the advice and agreement of Parks & Wildlife. A summary of site selection characteristics is shown in Appendix A2. Multiple potential translocation sites were initially identified and the mapped sites (Figure 3) represent those that "best" match criteria including:

- available existing disturbed or cleared land
- sited on the Mt Gibson ranges
- suitable regolith and terrain features
- location within mapped BGPA (2010) habitat
- proximity to known occurrence of plant records
- low likelihood of future mining or exploration
- accessibility for water reticulation establishment and irrigation for two years
- capacity for at least 200 individuals or more

In late May 2016 and April / May 2017, MGM held meetings, consulted with and supplied information to Parks & Wildlife. Department of Water and Environmental Regulation (DWER, formerly Office of the Environmental Protection Authority, OEPA) is provided with evidence of Parks & Wildlife acceptance by way of the Approved Translocation Proposal (Appendix A1) and email correspondence accepting the translocation sites within this plan (Appendices A2 and C).

The translocation program was initiated in 2016 with the first plantings taking place in July 2016. That work was enabled on the basis of an approved translocation proposal approved under the Wildlife Conservation Act 1950 by Parks & Wildlife in 2016 (see Appendix C). Figure 3 identifies the current sites contributing to the offsets required by MS1045 and Appendix E details background information on those sites. Established sites contributing to offsets required by MS1045 during 2016 include Sites 4, 14 and 16. Those sites have been extended during 2017 to provide greater capacity for planting of stock (Appendix A2).

In March 2021, MGM undertook further consultation with the Department of Biodiveristy, Conservation and Attractions (DBCA) regarding additional sites for translocation of remaining nursery stock in the vicinity of the Iron Hill Waste Rock Landform and Iron Hill South pit.

### 3.1.2 Sourcing plant materials from Iron Hill and Iron Hill South

The individuals from which cuttings would be sourced (held with an accredited Nursery under the Industry Accreditation Scheme Australia (NIASA)) will be taken into account when determining the location of the area in which to transplant them. Cuttings have been preferentially and initially sourced from Iron Hill and Iron Hill South (TPFL 1; 8).

Original stock held in nursery were supplemented with additional cuttings collected in 2015 and 2016 under Permits to Take Declared Rare Flora (Permit No: 28-1516 and 59-1617) (Figure 1).

**Figure 1: Juvenile D. *masonii* plants held at Nuts About Natives Nursey in early 2016**

### 3.1.3 Matters to consider to use plant materials for translocations

This section describes the use of plant material for translocations into areas to promote the viability of the species.

Ground preparation will be required at some translocation sites (Figure 2). Disturbed areas may be ripped to reduce the effects of compaction that may have occurred as a result of their previous use. Translocations into natural areas (Figure 3; Site 6) will not require any site preparation other than digging holes in which to put the cuttings/seedlings.

Cuttings and seedlings have been propagated in pots at a hygiene-accredited nursery and will be transported to Extension Hill mine site at the time of planting. The cuttings/seedlings will then be planted by hand, and placed in prepared holes of adequate depth. A fertiliser (for Australian natives) may be added to supplement the soil in each hole.

The cuttings/seedlings will be watered in and then drip irrigation will be made available to each plant. Cuttings/seedlings may be irrigated for one hour, twice per month for the first two summers and possibly winter period. This watering regime may be altered to suit the prevailing conditions.

It is anticipated that translocations will be established on a yearly basis for a period of two to three years. The planting work is scheduled to occur between 2016 and 2018.

Not all identified prospective translocation areas will necessarily be used. The program and schedule for preparing, establishing and planting nominated sites will be advised by MGM to Parks & Wildlife annually and reported to EPA as per condition 7-4 of MS1045. This will also include location, substrate, and source population.

The cuttings/seedlings will likely be derived from stock maintained at the nursery.

The nominal timeline for the roll-out of translocation activities is described in Table 4. Annual reporting by the proponents will also make recommendations including plans for the following year.

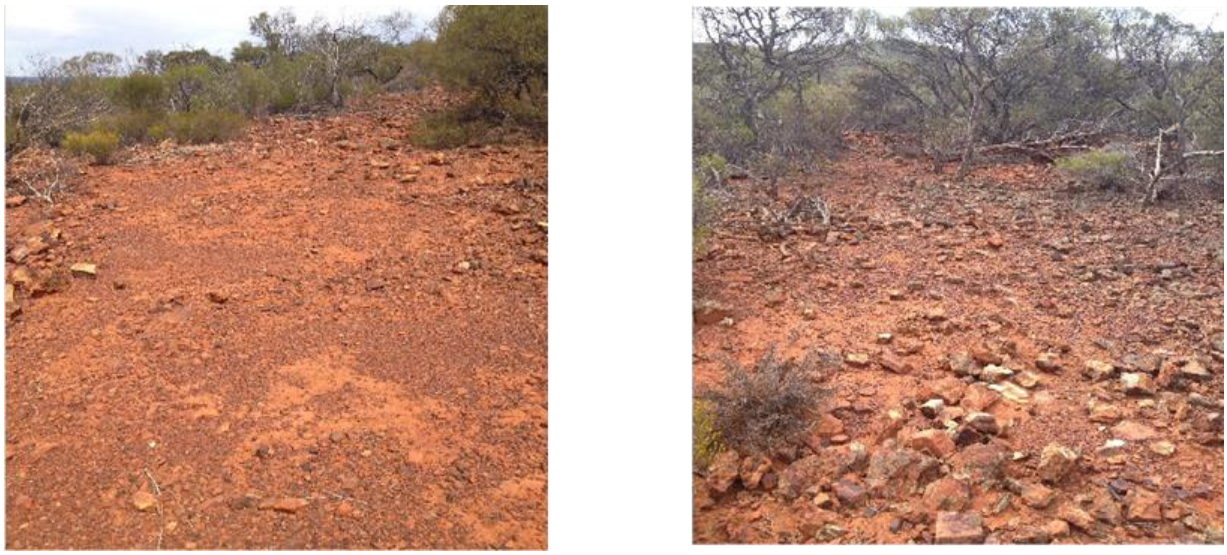

**Figure 2: Examples of suitable translocation sites at Mt Gibson Range**

### 3.1.4 Protection measures for fire, mining and exploration

Measures taken for protection against mining and exploration have involved consulting internally with MGM geologists and externally with EHPL to determine the likelihood of future resource targets. This has been done for each potential location and the likelihood of future disturbance rated as per the detail provided in Appendix A2. Those sites with a low likelihood have been chosen as the preferred locations.

Fire ignition may occur naturally (i.e. lightning strike) or as the result of human activity. Fire is known to temporarily eliminate and/or change the composition of floristic communities. *Darwinia masonii* individuals are prone to fire and likely to result in death of adults or young plants. The presence of MGM mining operations may reduce the likelihood of an extensive or out of control fire occurring. The emergency response team can respond rapidly to a fire due to their proximity in the Mt Gibson Ranges and available fire-fighting resources (personnel and gear), however they are not equipped to fight large scale bush fires.

Other risks as outlined by Appendix D include:

- Drought – addressed by a supplementary watering regime planned for the first two years at each site;
- Weeds - there is a weed monitoring and control program currently implemented as part of the Extension Hill & Extension Hill North Environmental Management Plan; and
- Grazing pressure – No significant grazing pressure on *Darwinia masonii* has been observed on the Mt Gibson Ranges since mining began in 2010. As a result, grazing pressure is not expected to be high. Small fences were erected around the first year sites (see photos Appendix E) to deter rabbits. Monitoring to date has indicated these fences are effective. These fences have been expanded at current sites and installed at new sites in 2017 (other than site 6 which is trialling the use of tree guards).

**Table 4: Nominal timeframe for D. *masonii* translocation activities**

| Activity | Timeline | Status |
|---|---|---|
| **2015 (Preparation year)** | | |
| Application for Scientific Permit | Autumn 2015 | Complete |
| Collection of Year 1 plant material (as required) | Winter-Spring, 2015 | Complete |
| Nursery propagation of Year 1 collected material | Winter 2015 - Autumn2016 | Complete |
| Selection of two to four suitable sites in Year 1areas | Winter 2015 | Complete |
| Seed collection from target areas | Spring 2015 | Complete |
| **2016 (Year 1 of Translocations)** | | |
| Site preparation of Year 1 sites | Autumn 2016 | Complete |
| Selected sites planted | Winter 2016 | Complete |
| Collection of Year 2 plant material for otherareas | Winter – Spring, 2016 | Complete |
| Selection of two to four suitable sites for Year 2areas | Winter 2016 | Complete |
| Nursery propagation of Year 2 collected material | Winter 2016 - Autumn2017 | Complete |
| Regular monitoring of Year 1 sites (more thanonce a month during month 1 and 2) | Spring 2016 | Complete |
| Monthly monitoring of Year 1 sites | Nov 2016 - Nov 2018 | Ongoing |
| **2017-18 (Years 2 & 3 of Translocations)** | | |
| Site preparation of Year 2 sites | Autumn 2017 | Complete |
| Selected sites planted | Winter 2017 | Complete |
| Annual monitoring of Year 1 sites | Spring 2017 | Complete |
| Regular monitoring of Year 2 sites (more thanonce a month during month 1 and 2) | Winter-Spring 2017 | Complete |
| Monthly monitoring of Year 2 sites | Spring 2017- Spring 2019 | Complete |

| | | |
|---|---|---|
| Selected trial sites planted as required; subjectto preceding monitoring of survivals | Winter 2018 | Complete |
| Annual monitoring of Year 1 and Year 2 sites | Spring 2018 | Complete |
| **2019-20 (Years 3 & 4 of Translocations)** | | |
| Annual monitoring of all sites | Spring 2019-2020 | Complete |
| **2021 – 2022 (Years 5 & 6 of Translocations)** | | |
| Identify additional sites for planting of remaining nursery stock | Summer 2020/21 | Completed |
| Site preparation of additional sites | Winter 2021 | Planned |
| Additional Year 5 sites planted | Winter 2021 | Planned |
| Regular monitoring of Year 5 sites (more than once a month during month 1 and 2) | Winter-Spring 2021 | Planned |
| Monthly monitoring of Year 5 sites | Spring 2021-Spring 2022 | Planned |
| Annual monitoring of Year 1-4 sites | Spring 2021 and Spring 2022 | Planned |

## 3.2 *Lepidosperma gibsonii* translocations

The following offsets are required (MS1045):

**OFFSET L1** ***Lepidosperma gibsonii* translocation program**

**(direct action)** Re-establishment of at least 863 *Lepidosperma gibsonii** as a result of implementing the proposal across the Mt Gibson Ranges (implementation by MGM).

* Note that BGPA (2010) research predicted that more than one genotype may exist per clump. It is not possible to determine how many genotypes occur in each clump when collecting material in the field. Therefore, it will be assumed that each clump represents at least one genotype for collection purposes.

**Table 5: Key milestone for L. *gibsonii* offsets**

| Offset | Milestone | Timeframe | Responsibility |
|---|---|---|---|
| **Offset L1** | Implement translocations of source plants to sites | By October 2018 | MGM |

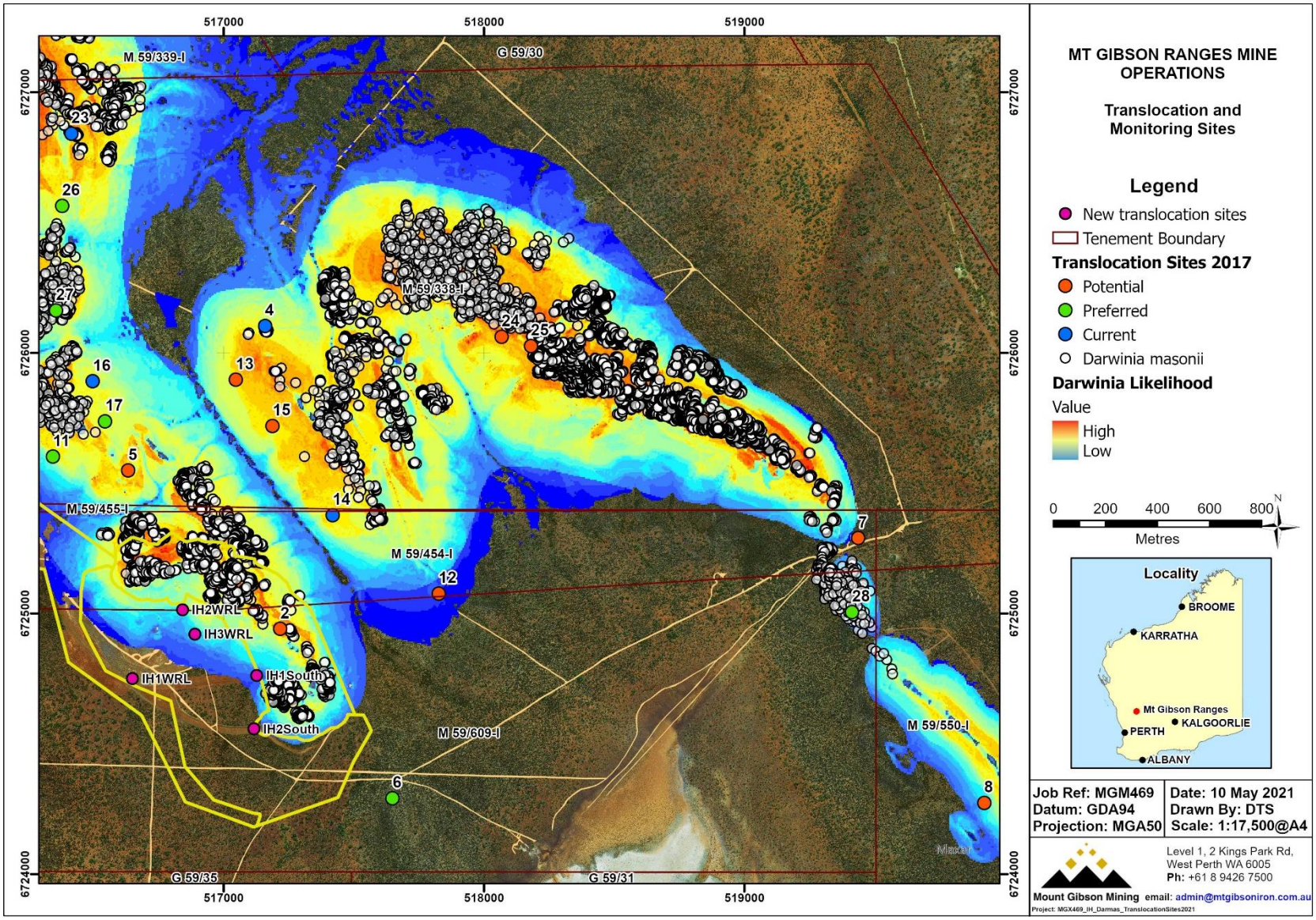


**Figure 3: Potential, current and preferred translocation sites (refer Appendices A2 and B2 for details)**

### 3.2.1 Matters to consider for identifying suitable L. gibsonii translocation sites

The proposal is based on taking plant material, propagating them under nursery conditions and establishing them in translocation sites on suitable habitat.

MGM will identify preferred sites, taking into consideration the following variables:

- Available existing disturbed or cleared land
- Sited on the Mt Gibson ranges
- Suitable regolith and terrain features
- Location within mapped BGPA (2010) habitat
- Proximity to known occurrence of plant records
- Very low likelihood of future mining or exploration
- Accessibility for water reticulation establishment and irrigation for two years
- Area of translocate at least 200 individuals or more

BGPA (2010) research identified the most suitable habitat for L. *gibsonii* to be gullies and slopes, with the following characteristics, each showing differing probabilities of L. *gibsonii* presence when considered on its own:

- Winter solar radiation 2pm <0.4 w.m-2.hr-1 (80%)
- Elevation > 340 m (29.5%)
- Slope (13.6%)

The high association of L. *gibsonii* with habitat that has relatively low receipt of light and heat is reflected by its requirement for low solar radiation. BGPA (2010) suggest that such habitats include gullies and slopes with low radiation receipt. Using those criteria, a "heat map" showing a probability of L. *gibsonii* presence on the Mt Gibson Ranges as well as on the surrounding areas overlain with the actual mapped locations of L. *gibsonii* plants is shown in Figure 4. This figure also shows potential and preferred translocation sites for L. *gibsonii*.

The shade of other plants (i.e. provision of an overstorey), representative of the same community type, will also reduce solar radiation when grown alongside L. *gibsonii* plants. Translocation trials also demonstrate greater L. *gibsonii* survival rates when planted in rocky or gravel substrates in comparison to clay or sand (BGPA 2010, Ruoss 2013). This is characteristic of the habitat in which the species occurs within and surrounding the Mt Gibson Ranges. Therefore, translocation areas will be selected with rocky or gravel substrates.

### 3.2.2 Sourcing plant materials from Iron Hill

Individuals from which clumps would be sourced will be taken into account when determining the location of the area in which to transplant them.

*Lepidosperma gibsonii* plants will be required from in situ sources at the Mt Gibson Ranges. A Permit to Take (200-1516) has been implemented to collect plant material from TPFL 2A and 2B (Iron Hill; Iron Hill South) during the winter of 2016. The plant material has been propagated at a NIASA accredited nursery and it is planned to plant them within select translocation sites. Approximately 1200 individual plants were planted at plot 11 in the winter of 2017.

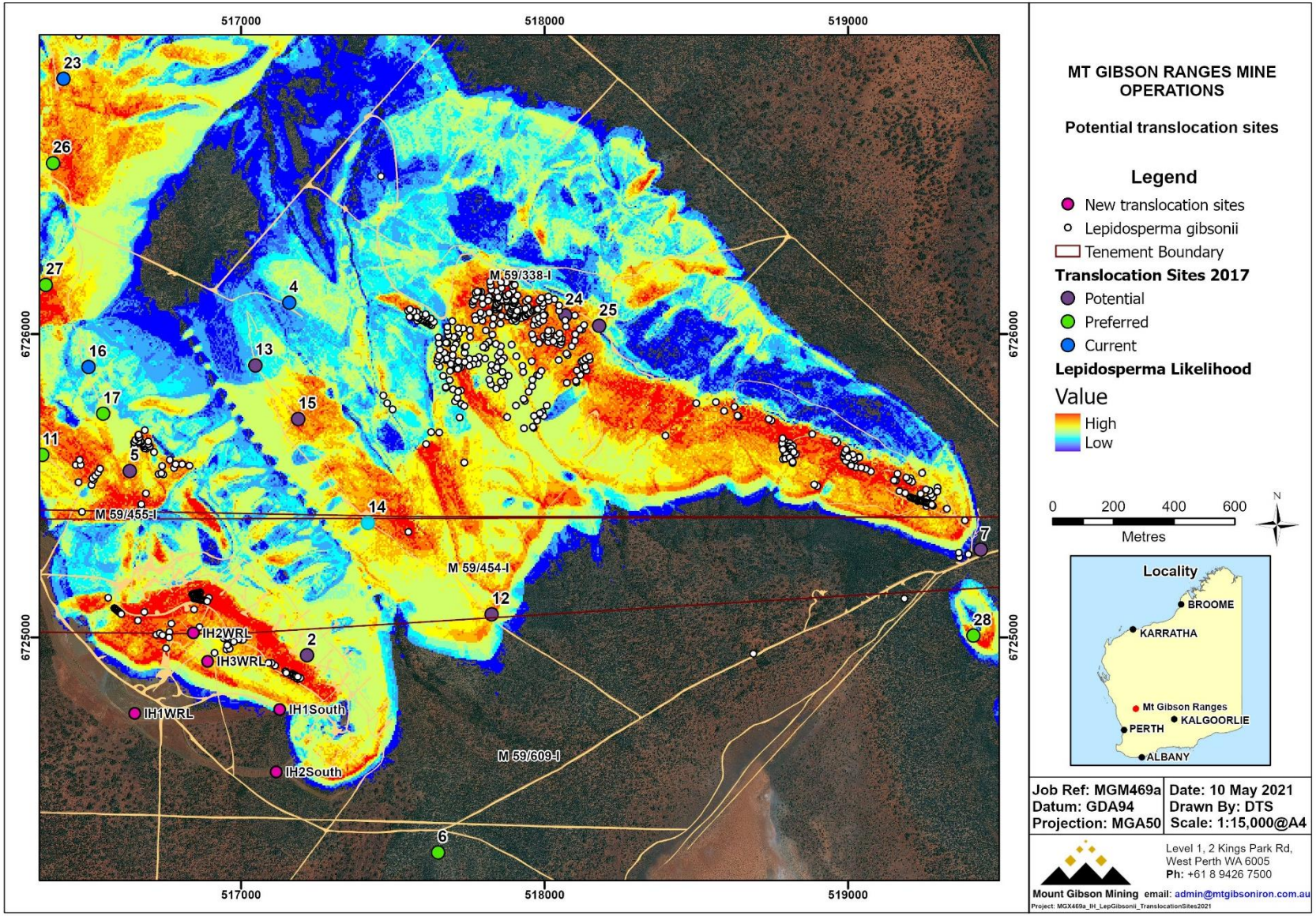


**Figure 4: Potential and preferred translocation sites for L. *gibsonii* (refer to Appendices A2 and B2 for details)**

Re-introduced plants (Translocation Proposal Approved by Parks & Wildlife – Appendix B1) will be planted by hand, and placed in prepared holes of adequate depth. A fertiliser (for Australian natives) may be added to supplement the soil in each hole. Green or dry brush collected from surrounding vegetation may be placed around the plants to:

- Serve as a mulch;
- Provide protection from grazing;
- Shade the plants from direct sunlight; and
- Re-introduce the seed from other species growing in adjacent vegetation.

The size of the sites and number of resulting plants may also be supplemented in the following year to meet success criteria. The survival and condition of plants in each plot will initially be recorded. Plants will be monitored regularly for the first eight weeks (more than once a month) and watered if required to assist with early survival and plant establishment.

### 3.2.3 Matters to consider to use plant materials for translocations

Examples of previously disturbed areas within the zone of predicted habitat may include:

- Drill pads and tracks that occur on slopes; or
- Historic tracks that may have led through gullies.

This type of translocation would directly replicate the methodology of the BGPA translocation trial and take into account site selection considerations (see above). The goal will be to establish a group of at least approximately 200 individuals per area and replicate the success of the original trial.

In April / May 2017, MGM held meetings, consulted with and supplied information to Parks and Wildlife. DWER is provided with evidence of Parks & Wildlife acceptance by way of the Approved Translocation Proposal (Appendix B1) and email correspondence accepting the translocation sites within this plan (Appendices B2 and C).

Ground preparation may be required at translocation sites. Disturbed areas may be ripped to reduce the effects of compaction that may have occurred as a result of their previous use.

It is anticipated that translocations will be established on a yearly basis for a period of two years. The program and schedule for preparing, establishing and planting nominated sites will be advised by MGM to DBCA and DWER within reports required by MS1045. This will also include location, substrate, and source population.

The nominal timeline for the translocation activities is described in Table 6. Annual reporting will also make recommendations about how to plan and progress the following year.

**Table 6: Nominal timeline for L. *gibsonii* translocation activities**

| Activity | Timeline | Status |
|---|---|---|
| **2016 (Preparation year)** | | |
| Application for Scientific Permit | May 2016 | Complete |
| Collection of Year 1 plant material (as required) | Winter-Spring, 2016 | Complete |
| Nursery propagation of Year 1 collected material | Winter 2016 - Autumn 2017 | Ongoing |
| Selection of two to four suitable sites in Year 1 areas | Summer 2016 / 2017 | Complete |
| **2017 (Year 1; Phase 1)** | | |
| Site preparation of Year 1 sites | Autumn 2017 | Complete |
| Selected sites planted | Winter 2017 | Complete |
| Collection of Year 2 plant material for other areas (if required for Phase 2) | Winter – Spring, 2017 | Currently not anticipated (adequate stock in Nursery) |
| Selection of one to three suitable sites for Year 2 areas | Summer 2017/2018 | Planned |
| Nursery propagation of Year 2 collected material (if required) | Winter 2017 - Autumn 2018 | Planned |
| Regular monitoring of Year 1 sites (more than monthlybetween month 1 and 2) | Spring 2017 | Ongoing |
| Monthly monitoring of Year 1 sites | Spring 2017- Spring 2019 | Ongoing |
| **2018-19 (Years 2 & 3; Phase 2)** | | |
| Site preparation of Year 2 translocation sites (if required) | Autumn 2018 | Planned |
| Selected translocation sites planted | Winter 2018 | Planned |
| Annual monitoring of Year 1 sites | Spring 2018 | Planned |
| Regular monitoring of Year 2 sites (more than once month during month 1 and 2) | Winter-Spring 2018 | Planned |
| Monthly monitoring of Year 2 sites | Spring 2018 – Spring2020 | Planned |
| Selected translocation sites planted (as required; based on monitoring for survival) | Winter 2018 | Planned |
| **2019-20 (Years 3 & 4 of translocations)** | | |
| Annual monitoring of Year 2 sites | Spring 2020 | Complete |
| Annual monitoring of all sites | Spring 2019 and Spring 2020 | Complete |
| **2021-2022 (Years 5 & 6 of translocations)** | | |
| Identify additional sites for planting of remaining nursery stock | Summer 2020/21 | Complete |
| Site preparation of additional sites | Winter 2021 | Planned |
| Additional sites planted | Winter 2021 | Planned |
| Regular monitoring of Year 5 sites (more than once a month during month 1 and 2) | Winter-Spring 2021 | Planned |
| Monthly monitoring of Year 5 sites | Spring 2021-Spring 2022 | Planned |

| Activity | Timeline | Status |
|---|---|---|
| Annual monitoring of Year 1-4 sites | Spring 2021 and Spring 2022 | Planned |

# 4 Completion Criteria and Adaptive Management

## 4.1 Offset D1: *Darwinia masonii* translocation program

The successful achievement of the objectives and targets of this offset are specified by meeting the long term completion criteria as below. For the purpose of progress reporting and providing adaptive management measures, further short term (approx. 2 years) and medium term criteria (3 – 5 years) are stipulated below.

***Short-term (approx. 2 years***

| Interim Criteria | Criteria for adaptive management response |
|---|---|
| Greater than 200 individuals in each plot (>70% survival)or greater than 70% survival overall, across all sites. | Less than 200 individuals in each plot (<70% survival), or <70% survival across all sites. |

Adaptive management: If monitoring results show that the short-term success criteria have not been met, supplementary plantings of cuttings/seedlings would occur in the following favourable season (MGM, 2016).

***Medium term (3-5 years)***

| Interim Criteria | Criteria for adaptive management response |
|---|---|
| Greater than 200 individuals in each plot (>70% survival) or greater than 70% survival overall, across all sites. | Less than 200 individuals in each plot (<70% survival), or <70% survival across all sites. |
| Flower production and seed viability in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL. | Flower production and seed viability of surviving individuals occurs at a lower rate* compared to individuals growing naturally within the nearest TPFL.** |

* more than 30% less

**measured annually between April and November the same time *Darwinia masonii* flower and set seed (see Section 5.1 – Monitoring).

Adaptive management: Given the positive value of periodic watering for the first two years, flower production and recruitment is expected to occur in the medium term. During years 3 to 5 the focus will be on measuring flowering, as it is flowering and seed production which will ultimately influence the presence of soil stored seedbank. As demonstrated by BGPA (2010) inter-fire recruitment is generally low for *Darwinia masonii*:

- *Darwinia masonii* are long lived (likely to ca. 100 years) and fire-killed.
- Most individuals recruit from long-lived soil-stored seedbanks in a single
- cohort following fire. Limited inter-fire recruitment may occur in older
- populations. Post-fire seedling recruitment is high in D. *masonii*, with as many as 3.2 seedlings per pre-fire adult, although ~90% of seedlings died over the first summer (albeit in a dry season).

Given the above, the measurement of flowering is more appropriate to determine if the translocated plants are reproducing and leading to the development of a soil-stored seedbank.

During years 3 to 5, if flowering and reproduction criteria are not met, an investigation will be undertaken to determine the cause. In this instance, DBCA will be consulted on the approach of the investigation. Aspects to be investigated for example may include:

- Plant health - Undertake PEA testing and qualitative health scoring of plants as per the Flora and Vegetation Management and Monitoring Plan (MGM 2017);
- Presence and impact of pests or disease.

In consultation with DBCA, following the investigation remedial action will be developed and implemented to specifically address the cause.

### *Long term criteria*

Evidence for recruitment (defined as emergence of new seedlings which are highly likely to be sourced from seed set by plants within translocation sites due to their close proximity to the translocation sites) will be monitored as per Section 5.1. This will not form part of the medium term completion criteria for the reasons specified above.

The focus for long term completion criteria will be evidence of healthy and mature plants which have been producing seeds for consecutive years. A measurement program will be conducted firstly in the medium term (less than 5 years) to show the presence of viable seed in a soil bank at translocation plots and, should it not be shown in the medium term, prior to the completion of the long term criteria.

| **D1 Completion Criteria** |
|---|
| Establishment[3] of at least 1,327 new *Darwinia masonii* as a result of implementing this plan. Plants are of a similar health rating to natural populations as measured by the ***Flora and Vegetation Management & Monitoring Plan*** (MGM 2017) |
| Flower production, seed set and seed viability for translocated individuals at rates equivalent to individuals growing naturally (based on background data) for a consecutive period of no less than twoyears. |
| **Presence of viable seeds in soils at translocation plots with germination rates** equivalent to individuals growing **naturally (based on background data)** |

Adaptive management: A representative portion of genetic material collected at Iron Hill prior to implementation of the proposal in the form of seedlings grown from cuttings (held in nursery until returned to the wild) and seed collected and stored will be maintained for the duration of the offsets program. In the event the offsets program is not successful, DBCA will be consulted on the use of that material for future species recovery actions which may lead to the successful implementation of offsetting the residual impact to the species as a result of implementing the proposal. In that instance, monitoring data gained during the implementation of this translocation program will be used to inform future actions.

Should the long term completion criteria not be reached within 10 years of this Plan being approved, condition 7-5 of MS1045 will be applied, thus:

> *7-5 Should the objective of the Darwinia masonii Offset Plan as required by condition 7-2 not be achieved within ten (10) years from implementation of the Plan, the proponent shall submit a revised Offset Plan to the satisfaction of the CEO, outlining management*

[3] With regard to *Darwinia masonii* 'Established' refers to a stage when an individual plant has demonstrated maturity by producing seed, has not been watered for at least three years and has gained biomass or height since watering ceased.

*strategies to achieve the outcome specified in condition 7-2. The revised plan must be submitted within three months of the ten (10) year period lapsing.*

Such strategies, at that time, could be used to apply indirect or contributory offsets as an alternative.

## 4.2 Offset L1: Translocation of *Lepidosperma gibsonii* plants

The successful achievement of the objectives and targets of this offset are specified by meeting the long term completion criteria as below. Short term (approx. 2 years) and medium term criteria (approx. 3 – 5 years) are also provided for the purpose of progress reporting and applying adaptive management measures.

### *Short term (approx. 2 years)*

The short term criteria below are defined in Section 3.6.1 of the Translocation Proposal (MGM, 2016b).

| Interim Criteria | Criteria for adaptive management response |
|---|---|
| Greater than 200 individuals in each plot (>70% survival)or greater than 70% survival overall across all sites. | Less than 200 individuals in each plot (<70% survival), or <70% across all sites. |

Adaptive management: If monitoring outcomes show that the short-term success criteria have not been met, supplementary plantings of clumps/seedlings would occur in the following favourable season (MGM, 2016b).

### *Medium term (3-5 years)*

| Interim Criteria | Criteria for adaptive management response |
|---|---|
| Greater than 200 individuals in each plot (>70% survival) or greater than 70% survival overall, across all sites. | Less than 200 individuals in each plot (<70% survival), or <70% survival across all sites. |
| Flower production and subsequent seed viability in surviving individuals at a rate equivalent to individuals growing naturally (based on background data) for two consecutive seasons. | Flower production and seed viability of surviving individuals occurs at a lower rate* compared to individuals growing naturally within the nearest TPFL.** |

*more than 30% less

**measured annually between late winter and early Spring

Flower production and recruitment is expected to occur in this medium term period. During years 3 to 5 the focus will be on measuring flowering, as it is flowering and seed production which will ultimately influence the presence of a soil stored seedbank. As demonstrated by BGPA (2010) inter-fire recruitment is generally low for *Lepidosperma gibsonii*:

- *Lepidosperma gibsonii* individuals recruit from long-lived soil-stored seedbanks in a single post-fire cohort. There is no evidence for inter-fire recruitment.
- Plants are long-lived (perhaps to ca. 100 years) and about half of plants exposed to fire appear to survive and resprout.
- Post-fire L. *gibsonii* recruitment averaged 4.2 seedlings produced per pre-fire adult, but ~75% did not survive to 2 years. Mortality among 4-6 year old seedlings averaged 3% per year.

Given the above, the measurement of flowering is more appropriate to determine if the translocated plants are reproducing and ultimately leading to the development of a soil-stored seedbank.

During Years 3 to 5, if flowering and reproduction criteria are not met, then an investigation will be undertaken to determine the cause. In this instance, DBCA will be consulted on the approach of the investigation. Aspects to be investigated for example may include:

- Plant health - Undertake PEA testing and qualitative health scoring of plants as per the Flora and Vegetation Management and Monitoring Plan (MGM 2017);
- Presence and impact of pests or disease.

Following the investigation and in consultation with DBCA, remedial action will be developed and implemented to specifically address the cause.

### *Long term criteria*

Evidence for recruitment (defined as emergence of new seedlings which are highly likely to be sourced from seed set by plants within translocation sites due to their close proximity to the translocation sites) will be monitored as per Section 5.1. This will not form part of the medium term completion criteria for the reasons specified above.

The focus for long term completion criteria will be evidence of healthy and mature plants which have been producing flowers for consecutive periods.

| **L1 final success criteria** |
|---|
| Establishment[4] of at least 863 new ***Lepidosperma gibsonii*** plants as a result of implementing this plan. Plants are of a similar health rating and height to natural populations as measured by the ***Floraand Vegetation Management Monitoring Plan*** (MGM 2017) |
| Flower production and subsequent seed viability from surviving individuals at rates equivalent to individuals growing naturally (based on background data) for two consecutive periods. |

Adaptive management: A representative portion of genetic material collected at Iron Hill prior to implementation of the proposal in the form of seedlings grown from cuttings and held in nursery will be maintained for the duration of the offsets program. In the event the offsets program is not successful, Parks & Wildlife will be consulted on the use of that material for future species recovery actions which may lead to the successful implementation of offsetting the significant residual impact to the species as a result of implementing the proposal. In this instance monitoring data gained during the implementation of this translocation program will be used to inform future actions.

Should the long term completion criteria not be reached within 10 years of this Plan being approved, condition 7-11 of MS1045 will be applied;

> *7-11 Should the objective of the Lepidosperma gibsonii Offset Plan as required by condition 7-8 not be achieved within ten (10) years from implementation of the Plan, the proponent shall submit a revised Lepidosperma gibsonii Offset Plan to the satisfaction of the CEO, outlining management strategies to achieve the outcome specified in condition 7-8. The revised plan must be submitted within three months of the ten (10) year period lapsing.*

[4] With regard to *Lepidosperma gibsonii* 'Established' refers to a stage when an individual plant has demonstrated maturity by not being watered for at least three years and has gained biomass such as an increase in height or diameter since watering ceased.

## 4.3 Offset L2: *Lepidosperma gibsonii* research

The aim of the research program is to confirm the taxonomic identity, and subsequently the numbers of *Lepidosperma gibsonii* plants on the surrounding plains of the Mt Gibson Range, to the west of the Great Northern Highway. Genetic sequencing analysis will examine the genotypic structure across samples of numerous individuals at locations (populations) where putative multi-taxonomic records have been made by DBCA in the past.

The successful achievement of the objectives and targets of this offset are specified by meeting the completion criteria as below. Short term (approx. 2 years) and long-term criteria (approx. 3– 5 years) are also provided for the purpose of progress reporting.

Once undertaken, the conduct and conclusion of this research infers that no adaptive management would be required as it will be devised and executed by industry experts (Curtin University scientists). The research results may be either conclusive or inconclusive, based on an objective determination of actual phylogenetic circumstances. That is, clear differences within and between populations may or may not be identified between putative taxa and/or geographic locations.

### *Short term (approx. 2 years)*

| Interim Criteria | Criteria for adaptive management response |
|---|---|
| Research has been awarded and relevant techniques are adopted to generate interpretable results. | Work methods/techniques require amendment for re-analysis of data. |

### *Long t erm (3-5 years)*

| Interim Criteria | Criteria for adaptive management response |
|---|---|
| Research findings give clear indications of genetic compositions of plant records in populations west of Great Northern Highway. | Additional sampling and testing warranted should nogeographic or taxonomic structure be interpretable. |
| Statement(s) of conclusion made about if and how to sample set of population records to identify plant taxonomic identify. | If taxonomic structure occurs, a conclusion must be made on how to use the research to discern the occurrence of *L.gibsonii* in populations on the surrounding plains, west of GNH. |

# 5 Monitoring

MGM will conduct monitoring until:

- such a time as the completion criteria for each of the offsets have been achieved (i.e. expected minimum of five years for the translocations of rare plants; or
- advised otherwise in writing by notice by the CEO of the administering authority

The results of the monitoring program will be included in the Environmental Offset Status Report to be submitted annually.

## 5.1 Offset D1 and L1 D. *masonii* and L. *gibsonii* translocations

The survival and condition of plants in each site will be recorded. Juveniles will be monitored regularly for the first eight weeks (more than once per month) and may be irrigated where required (subject to rainfall events) to assist with early survival and plant establishment (MGM, 2016).

After two months and during the summer period, translocation sites will be visited on a monthly basis to monitor and record plant survival over a period of two years, conduct maintenance of irrigation equipment and pumps, check water levels in water tanks and assess for herbivory (MGM, 2016).

After two years, irrigation equipment may be removed and sites will be monitored on an annual basis for survival and condition for a further 3 years. Second generation plants will be recorded and tagged if evident (MGM 2016).

Monitoring will continue to measure survival, flowering and recruitment on an annual basis until such time that long-term criteria for success have been met for two consecutive years (MGM, 2016).

The below summarises the monitoring planned to be carried out for each translocation site.

| # | Monitoring Activity andTiming | Parameter/s measures |
|---|---|---|
| 1 | Regulator Monitoring withinfirst two months (more thanonce a month) of planting | • Survival (BGPA health score for each plot)<br>• Baseline height (taken only once soon after planting)<br>• Condition (general description)<br>• Evidence of herbivory<br>• Check irrigation equipment |
| 2 | Monthly Monitoring from Months 3 to 24 after planting | • Survival (count of live plants)<br>• Condition (general description, evidence of flowering,seeding)<br>• Evidence of herbivory<br>• Check irrigation equipment |
| 3 | Annual Monitoring after twoyears of planting | • Survival (count of live plants)<br>• Height<br>• Condition (general description)<br>• Evidence of herbivory<br>• Check irrigation equipment<br>• Flowering, seed set and seed viability compared tonearest TPFL, new recruitment (evidence of soil seedbank) |

## 5.2 Offset L2 L. *gibsonii* research

Curtin University has been commissioned by MGM to conduct two phases of research on the matter. The commencement, execution and delivery of the items in the two phases will be monitored.

Phase 1 by:

| | | |
|---|---|---|
| 1 | Q1 2017 | Draft Phase 1 scope – released to MGM and DBCA (refer Appendix F) |
| 2 | Q2 2017 | MGM and Curtin sign Supply Agreement using final Phase 1 scope |
| 3 | Q3 2017 | *Lepidosperma spp* tissue collections from study area west of Great Northern Highway |
| 4 | Q3 2018 | *Lepidosperma spp* DNA analysis by provider |
| 5 | Q3 2019 | Establish and complete informatic and numerical analysis of genetic compositions |
| 6 | Q4 2020 | Phase 1 research paper issued (refer Appendix F) |

Phase 2 by:

| | | |
|---|---|---|
| 7 | Q1 2021 | Draft Phase 2 scope – released to MGM and DBCA |
| 8 | Q2 2021 | MGM confirms Supply Agreement using final Phase 2 scope |
| 9 | Q3 2021 | *Lepidosperma spp* supplementary tissue collections, west of Great Northern Highway |
| 10 | Q2 2022 | Additional informatic and numerical analysis of genetic compositions |
| 11 | Q3 2022 | Phase 2 research report |

Program progress will be monitored by attainment of the above items. Note as of Q1 2020, items (1) to (6) had been undertaken.

# 6 Reporting

As per conditions 7-4 and 7-10 of MS1045, MGM will submit a written report including monitoring data to DWER and DBCA every 12 months on the progress of the Offsets (D1 and L1) until such time as the project completion criteria has been met. The first report will be submitted within 15 months of this Offsets Management Plan being approved by DWER.

The Report will provide evidence on the status of objectives and targets, and milestones that were completed during the previous twelve months. Information may include:

- management actions that were undertaken and associated adaptive management actions,
- monitoring activities and associated reports, and
- the status in relation to specified completion criteria.

Supporting evidence may include relevant dates, third party assessments, audit reports, monitoring reports and photographs. Specific to each offset, the following reporting will be conducted.

| **Reporting requirements** | |
|---|---|
| 1. | Description of translocation sites (See Appendix E) |
| 2. | Source population. |
| 3. | Survivorship (total numbers and overall %) |
| 4. | Percentage and/or evidence of plants that are flowering, and producing seed in each translocation area. |
| 5. | Presence of any new recruits in the vicinity of **each translocation site**. |
| **6.** | **Requirement for additional plantings if success criteria has not been achieved or is not on track to be achieved** |
| 7. | **Requirement for additional plantings if success criteria has not been achieved or is not on track to be achieved.** |

# 7 References

Botanic Gardens and Parks Authority (BGPA) (2010). *Darwinia masonii and Lepidosperma gibsonii Conservation and Restoration Research. An integrated research program into the ex situ and in situ conservation, restoration and translocation requirements of Darwinia masonii and Lepidosperma gibsonii* May 2007 – June 2010. Unpublished report prepared by Botanic Gardens and Parks Authority (Kings Park and Botanic Garden) for Mount Gibson Mining Limited and Extension Hill Pty Ltd, Perth, WA.

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# APPENDICES

**Appendix A**
***Darwinia masonii* Translocation Proposal**

(Approved 2016 and 2018 addendum)

GOVERNMENT OF
WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Your ref:
Our ref:
Enquiries: Tanya Llorens
Phone: (08) 9219 9521
Email: Tanya.Llorens@dbca.wa.gov.au

Species and Communities Program

Mr Matthew Hamilton
Mount Gibson Mining Limited
Extension Hill

Dear Mr Hamilton

**APPROVAL FOR ADDENDUM TO TRANSLOCATION PROPOSAL FOR: *Darwinia masonii***

I would like to inform you that the amendments you sought to the existing approved translocation proposal for the above species of Declared Rare Flora have been approved by the Department of Biodiversity, Conservation and Attractions' Executive Director of Biodiversity and Conservation Science.

Approval was granted on 22 October 2018 for the amendments described in the document "Addendum proposal for the translocation of *Darwinia masonii*" Version 4a, that was forwarded to the department on 11 October 2018.

Please ensure that the proposed translocations are implemented as per the approved proposals, and their progress is reported to the department annually.

Yours sincerely

T. Llorens

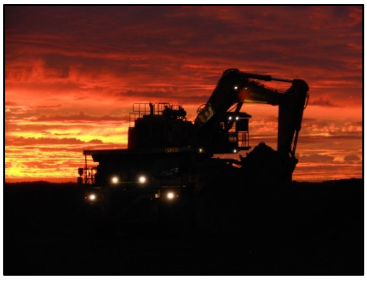
Tanya Llorens
BOTANIST
for the DIRECTOR GENERAL

24 October 2018

# MOUNT GIBSON MINING LIMITED

# ADDENDUM PROPOSAL FOR THE TRANSLOCATION OF DARWINIA MASONII

**Version 4a**
**Date: July 2018**



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## TABLE OF CONTENTS

**1. Introduction ..... 3**
**1.1 Purpose of the Proposal ..... 4**
**2. Translocation Proposal ..... 6**
**2.1 Additional Translocation areas ..... 6**
**2.2 Plant Source and Translocation methodology ..... 7**
**2.3 Maintenance and monitoring ..... 12**
**2.4 Criteria for success ..... 12**
**3. References ..... 18**

## List of Figures

FIGURE 1 ESTABLISHED AND POTENTIAL *DARWINIA MASONII* TRANSLOCATION SITES ..5
TABLE 1: CHARACTERISTICS OF THE IRON HILL WRL ..... 6
*FIGURE 2 UWA REHABILITATION TRIAL AREA ON THE EXTENSION HILL WASTE LANDFORM* ..... 7
FIGURE 3 PROXIMITY OF SOURCE *DARWINIA MASONII* SEED, TPFL POPULATIONS AND TRANSLOCATION LOCATION (WRL) ..... 10
FIGURE 4 CONNECTIVITY OF PROPOSED WORK WITH EXISTING POPULATION ..... 11

## List of Tables

TABLE 1: CHARACTERISTICS OF THE IRON HILL WRL ..... 6

## Appendices

APPENDIX 1 – SUMMARY TABLE OF CHANGES TO APPROVED TRANSLOCATION PROPOSAL

# 1. Introduction

Mount Gibson Mining (MGM) is seeking to supplement certain aspects of the seeding and translocation previously approved for *Darwinia masonii* to conduct additional work specifically on the Iron Hill Waste Rock Landform (WRL). MGM has sought advice from the Species and Communities Branch (SCB) of the Department of Biodiversity, Conservation and Attractions (DBCA) and this addendum aims to address the requirements specified by the SCB. This addendum is a subset of the Approved Translocation Proposal and is limited to information relevant to the proposed changes (Translocation Proposal Approval – Darwinia masonii Feb 2016).

The purpose of the proposed activities is twofold:

1) Using key learnings gained by laboratory based germination trials (BGPA 2010), apply the best identified method of germinating *Darwinia masonii* to field based trials on the Iron Hill WRL in the absence of artificial irrigation; and

2) Advance previous and ongoing translocation trials conducted on the Extension Hill WRL by translocating seeds and juveniles on a larger scale to the Iron Hill WRL and compare the effect of irrigation versus no irrigation.

BGPA (2010) demonstrated that *Darwinia masonii* can be translocated to a disused drill pad with ~80% survival rates when irrigated for the first two summers. A second trial conducted by Ruoss (2013) demonstrated that in the absence of irrigation, translocated *Darwinia masonii* can survive in 'rocky ridge' and 'gravel slope' substrates but with a much lower survival rate (~13%). MGM (2018) have subsequently demonstrated that wild grown seedlings can be translocated and that those translocated *Darwinia masonii* can survive in a constructed waste rock landform (100% survival after 3 years) and produce viable seed at a rate equivalent to or better than nearby natural populations when irrigated for only the first summer.

This trial will expand upon the previous trials by examining the effect of not irrigating translocated plants and also determining if *Darwinia masonii* can germinate from treated seed in a constructed waste rock landform (WRL). *Darwinia masonii* has naturally low recruitment rates in the absence of a disturbance, such as a fire. MBS (2016) recorded only two new seedlings across 41 monitored plots, so whilst it has been demonstrated that the Extension Hill WRL trial plants are producing viable seed, the likelihood of natural recruitment in this small population is limited unless there is a disturbance event. This work aims to demonstrate whether that seed would be likely to germinate in the event of a disturbance and thus preserve the population, by using pre-treated seed, with smoke water treatments essentially replicating the effect of the disturbance. The rates of germination and survival recorded in this trial will also assist in determining appropriate seeding rates for any future broadscale seeding programs which may be implemented as a means of re-establishing this species in future rehabilitation programs.

Potential translocation sites for *Darwinia masonii* are currently limited by the logistics of installing irrigation systems. If it can be demonstrated that irrigation is not vital to achieve reasonable survival rates, larger and more remote translocations would be available as an option as part of future rehabilitation programs.

While the overall purpose of the seeding described by this addendum do not differ largely from that of the Approved Translocation Proposal (ATP), only the methodology does. The change in

methodology is included here for completeness of information. The additional work proposed here for the translocation of juveniles differs from the ATP as all previous translocations have applied irrigation for the first one or two years post planting.

Importantly, the Iron Hill WRL sits within an Approved Development Envelope (Ministerial Statement 1045). The work described by this addendum are not intended to meet requirements of either Ministerial Statement 1045 or Ministerial Statement 753. Rather, the translocations described by this addendum are for research purposes focused on broadscale restoration practices and may be removed at a later date while Ministerial Statement 1045 (MS1045) remains in effect. Upon implementation of the Iron Hill Mine Closure Plan (MGM 2017), the translocations may remain established and no plants would need to be removed.

## *1.1 Purpose of the Proposal*

The ATP describes the following:

*The purpose of the actions is to augment outcomes of the experimental phase of the translocation study (BGPA 2010; Appendix 2) and enact certain requirements of the species' recovery plans.*

The species recovery plans and actions mentioned above are those required by Ministerial Statement 753. The implementation of the ATP has seen a number of translocation plots developed to support Ministerial Statement 753 (MS753, Extension Hill) and conditions of MS1045 (Iron Hill). Whilst MGM considers the *Wildlife Conservation Act 1950*, the *Environmental Protection Act 1986* and their jurisdictions to be separate, to alleviate confusion, this addendum also clarifies the translocation plots which relate to each Ministerial Statement.

Figure 1 shows the location of established and potential additional *Darwinia masonii* translocation plots. The plots meeting the condition requirements of MS1045 are given numbers 4, 6, 14, 16 and 17. Plant material cultivated to establish these plots has been derived from TPFL1, Iron Hill (Figure 2). The plot supporting the requirements for MS753 is Plot 23 and plant material cultivated to establish this plot was sourced from TPFL 2, Extension Hill. The differentiation of plots is also due to the requirement to prevent genetic mixing of source populations. For this reason plant source material derived from Extension Hill (TPFL 2) applies to MS753 and plant source material derived from Iron Hill (TPFL 1) applies to MS1045. Also, MGM explored a further six plots within mapped areas of likely habitat to support requirements of MS753, however each of these plots was not pursued due to either the potential for future disturbance, unsuitable substrate or restricted access. Note the original trial translocation plot was established in support of MS753 at Plot 4.

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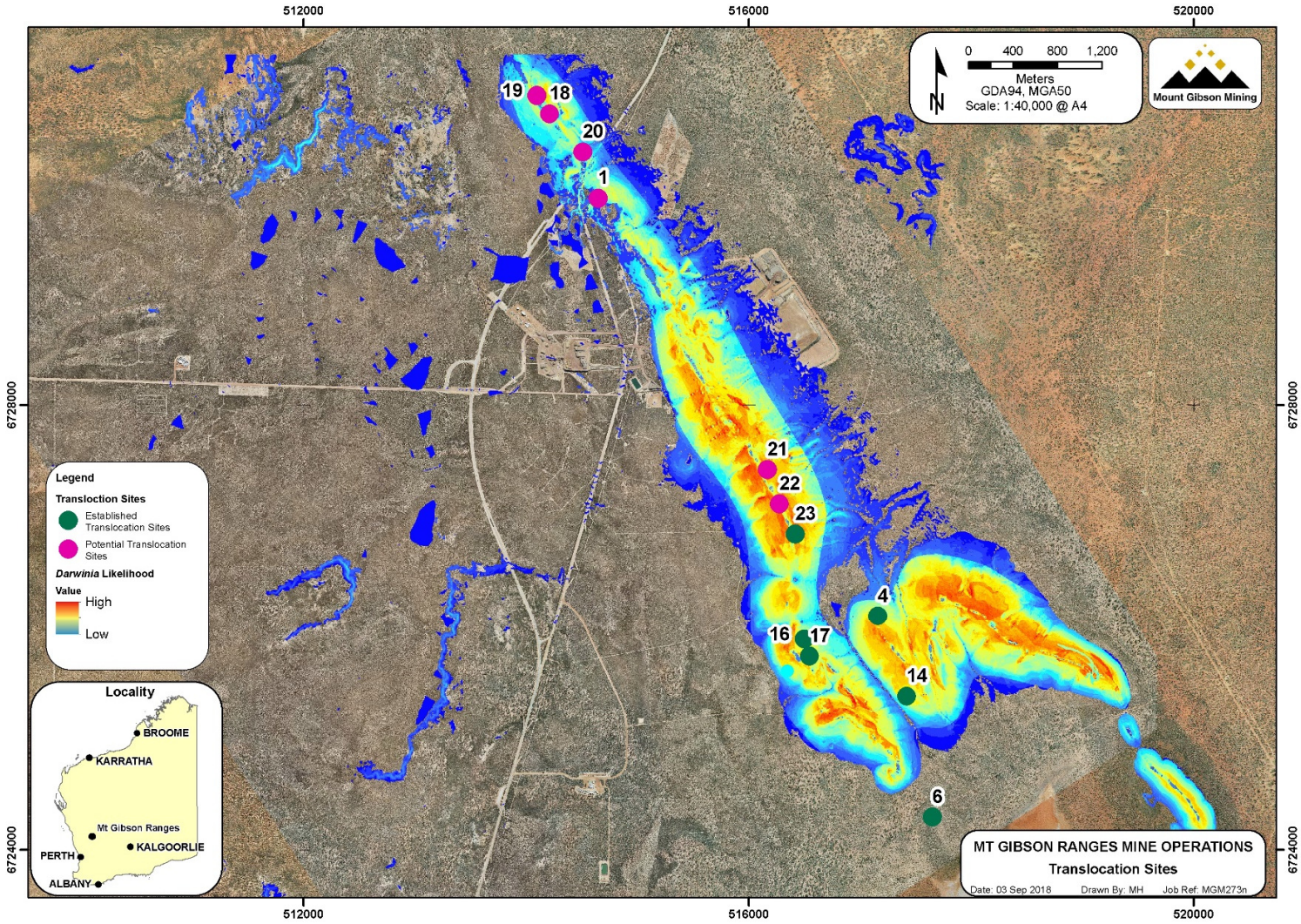


**Figure 1 Established and Potential *Darwinia masonii* Translocation Sites**

# 2. Translocation Proposal

## *2.1 Additional Translocation areas*

**Iron Hill WRL – Description**

The ATP provides a description of the Extension Hill WRL (with source stock from within the footprint of MS753). The activity proposed by this addendum will be at the Iron Hill WRL as the seed and juveniles from cuttings available were obtained from TPFL 1, Iron Hill, adjacent to the location of the Iron Hill WRL (Figure 3) and the proposed work conducted on the Iron Hill WRL may be extrapolated to a broader scale such as the Extension Hill WRL in the future. Table 1 below provides a description of the Iron Hill WRL and Figure 3 shows the approximate location. The only key physical difference between the Iron Hill WRL and the Extension Hill WRL is the location. The physical conditions are very similar as they have both been constructed from waste rock derived from mine pits with similar geology.

At the completion of mining the Iron Hill hematite deposits, the Iron Hill WRL will be shaped to have 15 degree slopes, approximately two – three lifts of 10 – 15m in height, berms of 10m width and the top will remain flat or slightly concave. Topsoil will be applied at a depth of 100mm (slopes) to 200mm (flat top) and this will include topsoil derived from vegetation clearing conducted within TPFL 1 (Figure 3). As a result, some of this soil may contain *Darwinia masonii* seed. The topsoil will be deep ripped on contour using a winged tyne and seeded by hand with a mix of common species native to the Mt Gibson Ranges. Whilst the seeding to be described by this addendum may be undertaken around the same time as that of common species, it will be done separately within trial areas.

**Table 1: Characteristics of the Iron Hill WRL**

| Site ID | X_MGA50 | Y_MGA50 | Elevation (m) | Outside Slope (º) | Aspect | Description |
|---|---|---|---|---|---|---|
| **IH WRL** | 516664 | 6724960 | Between 340mAHD to380mAHD | 15º | Southwest | Mined debris and waste rock landform comprised of mined rock and earthen overburden |

**Seeding trials – Iron Hill WRL**

The approved translocation proposal states the following:

> *This part of the trial will complement the research of Sebastian Lamoureux B.Sc (UWA PhD Candidate) by building on the outcomes of the research program, by testing the direct sowing of pre-treated, as well as, untreated D. masonii seed. Successfully proven dormancy breaking seed pre-treatments include burial and smoke water application (BGPA 2010). The early recommendations from the research program (and associated approved translocation program; Figure 1-A and 1-B) will inform site preparation requirements for these trials..*

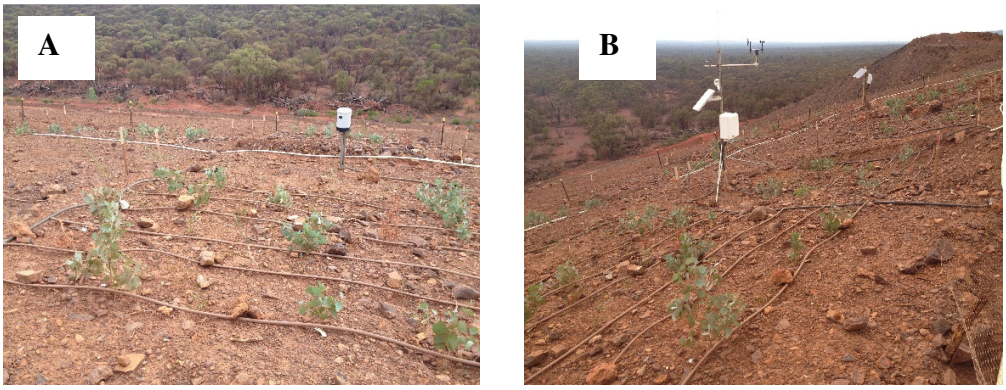


***Figure 2 UWA rehabilitation trial area on the Extension Hill waste landform***

The proposed seeding trial will differ from the previously approved as all seed will be treated as per the treatment method with the highest rates of success identified by BGPA (2010). BGPA (2010) had the most success with burying seed for 9 months and treating with smoke water. This resulted in a germination rate of 90% (BGPA, 2010). This trial will involve burying seed for approximately 6 or 9 months before treating with smoke water and seeding the Iron Hill WRL.

**Translocations – Iron Hill WRL**

The approved translocation proposal does not specifically detail the translocation of juvenile plants grown from nursery onto the Iron Hill WRL. There is adequate nursery stock available to conduct an additional translocation onto the newly formed Iron Hill Waste Rock Landform. MGM has demonstrated *Darwinia masonii* can be translocated successfully to similar landforms with a trial conducted on the Extension Hill Waste Rock landform yielding 100% success and strong rates of growth (MGM 2018). The work at the Iron Hill WRL will build upon the learnings and success reported in MGM (2018) by planting numerous juvenile plants. The approximate location of the Iron Hill WRL is shown by Figure 3. The WRL is a created landform which is spatially contiguous with wildstock *D.masonii* at Iron Hill and Iron Hill South.

## *2.2 Plant Source and Translocation methodology*

The approved translocation proposal states the following:

> *Where seeding is conducted, irrigation will be made available to seedlings at the end of the winter period. Seeding will be based on the following assumptions:*
>
> - *Seed germination of approximately 90% (following pre-treatments; based on BGPA, 2010 research outcomes),*

- *Approximately 10% of seedlings may survive to the end of winter (based on BGPA, 2010 research outcomes),*
- *One plant/ 2 $m^2$,*
- *Trial area of 100$m^2$ in the first year of the trial.*

*On the waste landform and other disturbed areas (e.g. Type B areas), based on outcomes of the UWA translocation research program, more than one trial area with differing soil treatments may be used to determine the success of this methodology. On natural areas, the trial area will be restricted to the one area. This conservative approach builds on D. masonii seed research to-date (i.e. BGPA, 2010) and the outcomes of the UWA D. masonii translocation program.*

*The size of the trial area and number of resulting plants may then be supplemented in the following year to meet success criteria (defined in Section 4.6).*

The seed trials proposed for the Iron Hill WRL will differ to the above as irrigation will not be applied to seeded areas. The purpose of this trial is to determine the viability of seeding as a method of restoration. For example, WRL's.

750g of *Darwinia masonii* seed collected from TPFL 1 (Figure 3) was buried in May 2018. The seed will remain buried for approximately 6 or 9 months, 2cm below the ground surface and then be removed and smoke treated as per BGPA (2010). Approximately 750g of *Darwinia masonii* seed will remain in storage for future trials.

Seed will be spread over areas 10m x 10m (100m2) by hand at a rate of 75g per area, allowing for up to 10 areas. Topsoil will be added to all seed prior to spreading at a rate of 4 parts soil to 1 part seed with the intent of aiding dispersion and setting of seed within the soil (ie to reduce the chance of it blowing away). Seed viability testing conducted by Nuts about Natives (NaNs) on a portion of the seed collected from TPFL1 demonstrated an average of 27% viability or 62 viable seeds per gram. Assuming a germination rate of 90%, this may generate 4185 germinants per 75g of seed. However, without the assistance of irrigation, only ca.10% of these may survive to the first winter, leaving 400 seedlings or approx. 4 plants per m2 within a 100m2 plot (based on BGPA 2010 research outcomes) Considering the longer term survival rate may be less than 10% without the assistance of irrigation, the result may be 1 to 4 plants per m2.

5 areas will be established immediately after the WRL is ripped which is anticipated to be around November / December 2018. Hand broadcasting of a native seed mix will also occur at this time. Another 5 areas will be established in March 2019. This will allow for a comparison between seed which has been buried for approximately 9 months and then sown in Autumn, and seed that is buried for approximately 6 months and sown in early summer, immediately after ripping of the rehabilitated area.

Approximately half of the soil spread on the Iron Hill WRL will have been derived from land covering TPFL 1 (Figure 3), so may contain a seed bank of *Darwinia mas*onii. The other soil spread will be derived from beneath vegetation clearing outside of TPFL 1 and will not contain a seed bank of *Darwinia masonii*. So, five of the areas will be located within soil derived from TPFL 1 and the other half will be located within soil not derived from TPFL 1. This will allow for a comparison of the two sources and the effect of the soil stored seed bank on overall germination rates, however it is anticipated that any effects of soil stored seed will be negligible due to the seeding rate applied and the low rates of recruitment without treatment or disturbance such as fire (Section 1). It is noted

that there has not been any *Darwinia masonii* germination recorded from the soil stored seed in the Extension Hill WRL rehabilitation monitoring plots to date, however plants have been recorded growing from the soil stored seed in topsoil stockpiles. 10mx10m quadrats established outside of the *Darwinia masonii* trial seed plots for monitoring of species diversity and density required by the Iron Hill Mine Closure Plan, will allow for comparison of the trial plots with areas that may have a soil stored seed bank derived from TPFL 1.

With regard to the juvenile *Darwinia masonii* plants to be translocated from nursery stock onto the Iron Hill WRL, there is no change to the plant source and the Iron Hill WRL represents an additional land area. The Iron Hill WRL is described in section 2.1 above. The cuttings for this work have been collected from TPFL 1 and grown at the Nuts about Natives accredited nursery, in accordance with the ATP.

It is considered that due to the high rate of success demonstrated by the Extension Hill WRL trial, a strong rate of survival may be possible without the assistance of irrigation. The Extension Hill WRL trial (MGM 2018) delivered 100% survival, strong rates of growth and was watered for a single summer from June 2015 to February 2016. Previous trials conducted by BGPA (2010) within previously disturbed areas demonstrated high rates of survival (81%) after 8 years with two years of irrigation, but low rates of survival (13%) where irrigation was not applied.

This trial proposes to establish six approx. 15m x 15m plots of 100 plants each on the Iron Hill WRL. Three will be irrigated to at least the end of the first summer and three will not be irrigated. Each plot will be no closer than 30m from another plot and the irrigated vs non-irrigated interspersed with each other thereby allowing the plots to expand across a range of the landform. This will build upon the success of the Extension Hill WRL trial and determine if it is possible to translocate juveniles from cuttings to WRL's on a large scale without the assistance of irrigation.

The Iron Hill WRL is in close proximity to the source and remaining wildstock *D. masonii* population (Figure 4). This approach enables the restoration of land in and around the Iron Hill meso-scale and evidences future plans to establish the viability of applying the *Darwinia masonii* seed and juvenile plants on a broad scale for any future restoration effort.

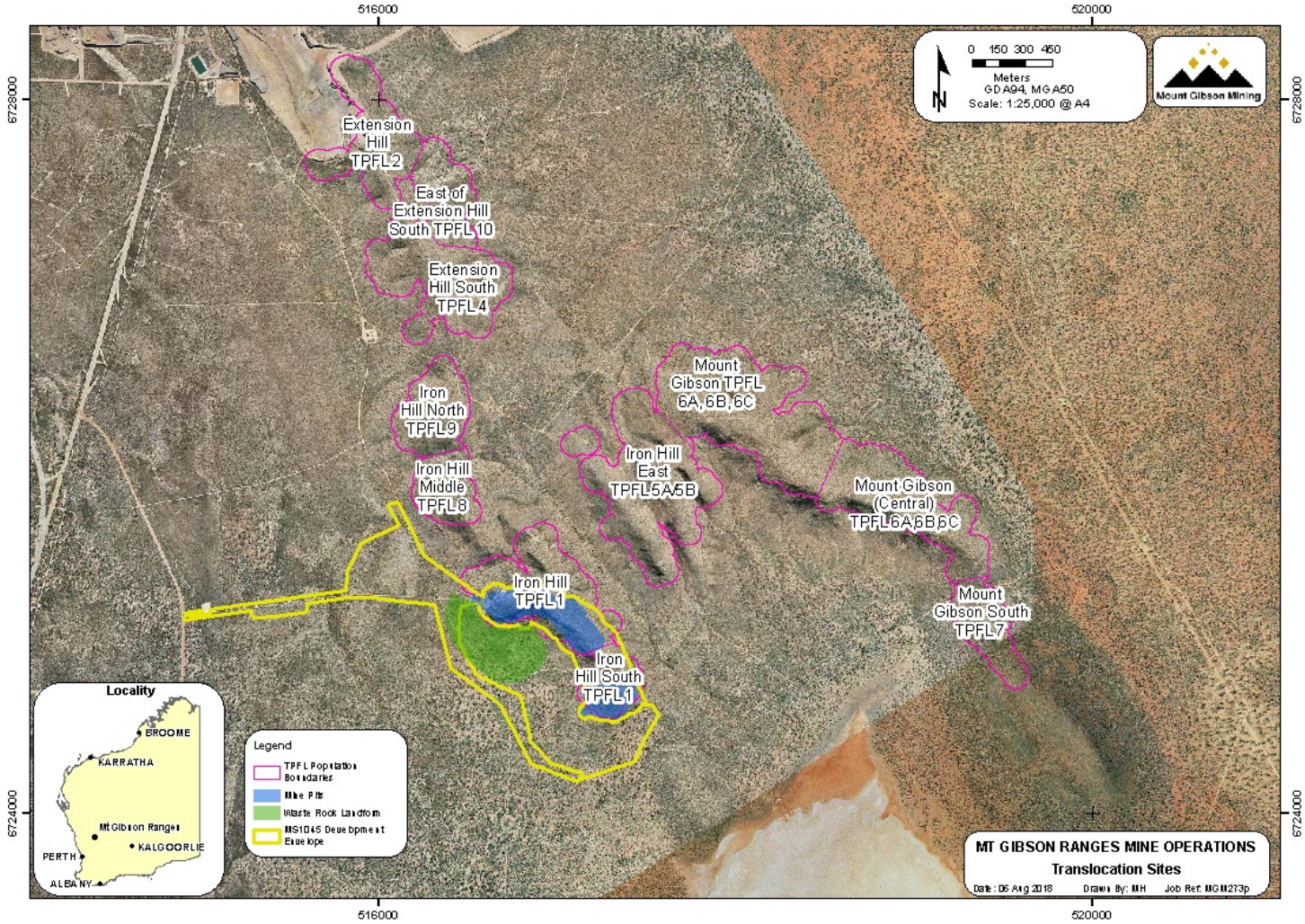


**Figure 3 Proximity of source *Darwinia masonii* seed, TPFL populations and translocation location (WRL)**

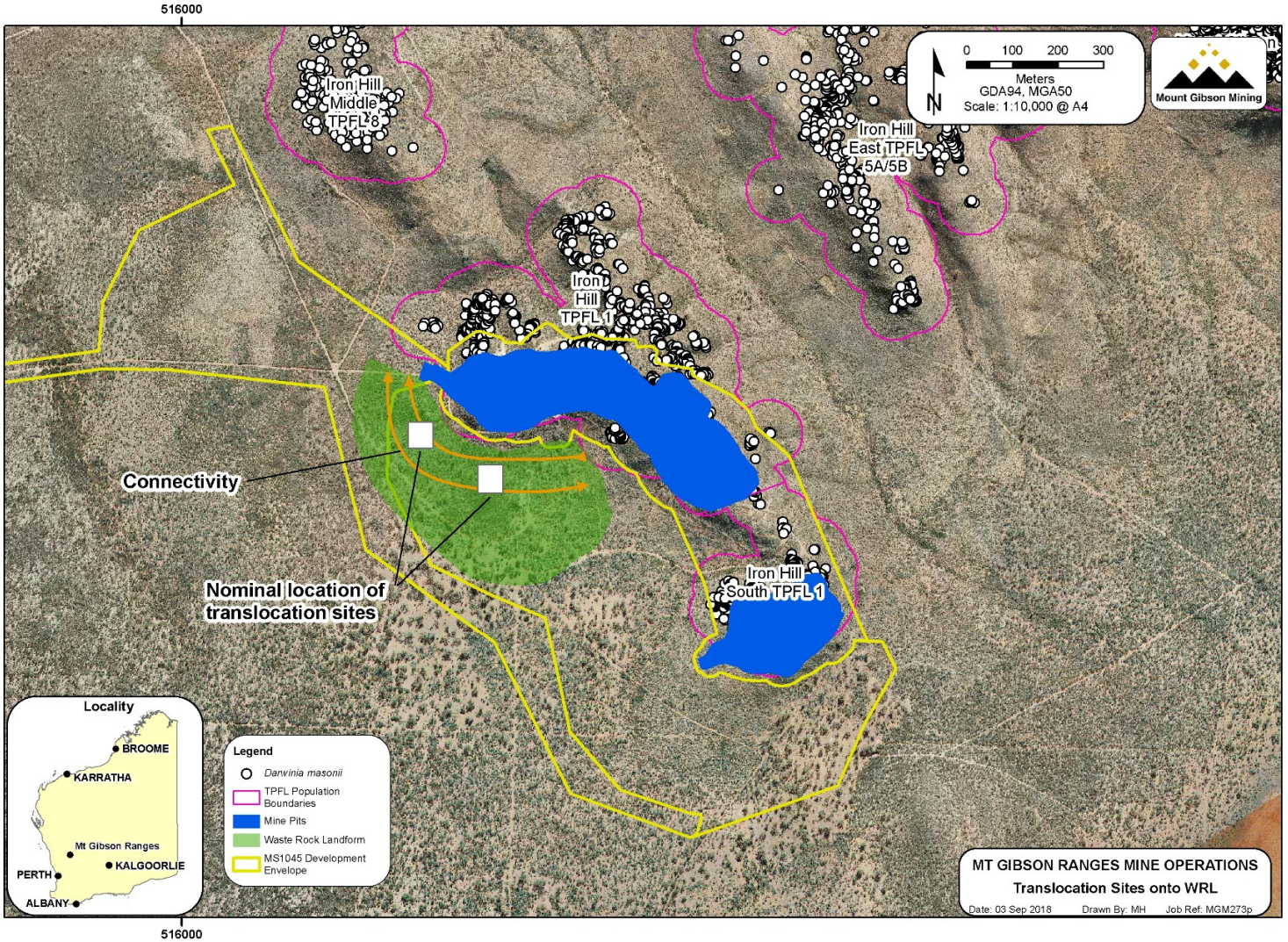


**Figure 4 Connectivity of proposed work with existing population**

## 2.3 Maintenance and monitoring

The approved translocation proposal states the following:

> *The survival and condition of plants in each trial area (approx. 100 m$^2$) will initially be recorded. Cuttings/seedlings will be monitored weekly for the first eight weeks and spot irrigated if required (subject to rainfall events) to assist with early survival and plant establishment.*
>
> *After two months and during the summer period, translocation sites will be visited on a monthly basis by site personnel to monitor and record plant survival for a period of two years, conduct maintenance of irrigation equipment and pumps, check water levels in water tanks and assess for herbivory (and consider using fencing if the plants are at risk of extensive herbivory).*
>
> *After two years, irrigation equipment will be removed and D. masonii populations will be monitored on an annual basis for survival and condition for the period of five years after their translocation. Second generation plants will be recorded and tagged if evident and monitored thereafter.*
>
> *After five years, monitoring will continue to measure survival, flowering and recruitment on an annual basis until such time that long-term criteria for success have been met for three consecutive years.*
>
> *Seed trials will be monitored to meet the criteria for success as per the cuttings/seedlings trials (described above) and as described in the Extension Hill Closure Plan (2015).*
>
> *Seed trials will be monitored to meet the criteria for success as per the cuttings/seedlings trials (described above) and as described in the Extension Hill Closure Plan (2015).*

The difference for monitoring being proposed for the additional translocated juvenile plant plots, in comparison to the above, is the frequency will be reduced to quarterly for the first two years, weekly monitoring will not be undertaken and annual monitoring will cease after 5 years. It is likely that the mine site will be in either a care and maintenance or closure phase at the time of the work, with limited on site resources available for monitoring. Quarterly monitoring is considered adequate as it will generate sufficient data on the changes throughout seasons and determine if success criteria are being met. Long term success criteria does not apply to the trials, therefore removing the need to continue monitoring after 5 years (see Section 2.4). Translocated juvenile plants will be tagged to identify their source and monitored for survival and the presence of flowers.

The seeding areas will be monitored quarterly for the first two years and focus on germination and establishment within the quadrats described by Section 2.2.

After the first two years, because plants will have established, annual monitoring is considered sufficient.

## 2.4 Criteria for success

**Juvenile Cuttings**

In relation to the translocation of juvenile *Darwinia masonii* plants, the ATP states the following in relation to success criteria:

*Short Term Criteria (2 years with irrigation)*

| Success Criteria | Failure Criteria |
|---|---|
| *Greater than 200 individuals in each trial area (>70% survival)* | *Less than 200 individuals in each trial area (<70% survival)* |

*If monitoring outcomes reflect that the short-term success criteria have not been met, supplementary plantings of juveniles from cuttings/seedlings may occur in the following year.*

*Medium term criteria (2-5 years, without irrigation)*

| Success Criteria | Failure Criteria |
|---|---|
| *Greater than 200 individuals in each trial area (>70% survival).* | *Less than 200 individuals in each trial area (<70% survival)* |
| *Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL.* | *Flower production and seed set of surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL.* |
| *Recruitment of second generation individuals' that are equivalent to recruitment rates of individuals growing naturally within the nearest TPFL.* | *Recruitment of second generation individuals' is less than recruitment rates of individuals growing naturally within the nearest TPFL.* |

*Given our learnings of the effects of watering on this species for the first two years, we are expecting flower production and recruitment to occur in this medium term period. However, if there is failure then we will continue to monitor them with the expectation that flower production and recruitment will occur in the longer term.*

*Long term criteria (at 5 years)*

| Success Criteria | Failure Criteria |
|---|---|
| *Survival rates are equivalent to those D. masonii individuals growing naturally within the nearest TPFL.* | *Survival rates are not equivalent to those D. masonii individuals growing naturally within the nearest TPFL.* |
| *Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL.* | *Flower production and seed set in surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL.* |
| *Recruitment of second generation individuals' that are equivalent to recruitment rates of the individuals growing naturally within the nearest TPFL.* | *Recruitment of second generation individuals' is less than recruitment rates of the individuals growing naturally within the nearest TPFL.* |

This work provides a comparison between irrigated and un-irrigated translocations to determine survival in the absence of irrigation. The success and failure criteria listed above is not appropriate since this is a comparative assessment, and the plants atop the WRL do not form part of an approved Ministerial Statement offset. The criteria outlined above will continue to be applied, however survival for the non-irrigated plots will be assessed against a 35% short and medium term success criteria as opposed to 67% for irrigated plots (changed to 67% as this is equal to 200 or more plants surviving from 300 planted). The reduced criteria reflects outcomes of previous research (Ruoss 2013, BGPA 2010) indicating reduced survival in the absence of irrigation. Furthermore, long term monitoring (after 5 years) will not be applied as it is not necessary to meet the objectives of the proposed trial which as stated above is to understand survival of non-irrigated plants.

Should survival of non-irrigated plots be greater than 35% this will present a viable case for broadscale restoration without the extra cost and effort required with irrigation. In the future, beyond the scope of this proposal, a small number of cuttings could be collected from natural populations without risk to those populations and a large number of plants grown from cuttings. For example 3000 – 4000 juvenile plants grown from 1000 cut wildstock "parents" could potentially result in 1200 – 1600 long term surviving plants (assuming 40% survival).

The plots will be monitored for survival quarterly during the first two years and then annually for 3 years.

The data generated from this work may be applied to future translocations to determine, in consultation with DBCA, whether irrigation is beneficial.

Based on the above, the success criteria proposed will supersede the content of the ATP (and stated above in italics) as follows:

Short Term Criteria (2 years with irrigation)

| Success Criteria | Failure Criteria |
|---|---|
| Greater than 200 individuals in the irrigated trial area (>67% survival) | Less than 200 individuals in the irrigated trial area (<67% survival) |
| 35% or greater survival in the non-irrigated trial area | Less than 35% survival in the non-irrigated trial area |

If monitoring outcomes reflect that the short-term success criteria have not been met, supplementary plantings of juveniles from cuttings/seedlings may occur in the following year.

Medium term criteria (2-5 years, without irrigation)

| Success Criteria | Failure Criteria |
|---|---|
| Greater than 200 individuals in the irrigated trial area (>67% survival)<br>35% or greater survival in the non-irrigated trial area | Less than 200 individuals in the irrigated trial area (<67% survival)<br>Less than 35% survival in the non-irrigated trial area |
| Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL. | Flower production and seed set of surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL. |

**Seeding**

In relation to the seeding trial, the ATP states the following in relation to success criteria:

*Short term criteria (approx. 2 years, with irrigation)*

*Seeding Trials*

| ***Success Criteria*** | ***Failure Criteria*** |
|---|---|
| *Survival of some individuals in each trial area to inform future seed density requirements.* | *Survival of no individuals in each trial area.* |

*Note that we have not specifically stated a number of individuals for seed trials because no information is currently available to determine what can be expected in comparison to the translocation of cuttings/seedlings. If no germination or survival of seedlings occur in this period then this aspect of the translocation trial may be abandoned or repeated with differing treatments.*

*Medium term criteria (2-5 years, without irrigation)*

*Seeding Trials*

| ***Success Criteria*** | ***Failure Criteria*** |
|---|---|
| *Greater than 35% survival in each trial area.* | *Less than 35% survival in each trial area.* |
| *Flower production and seed set in 25% of surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL.* | *Flower production and seed set in 25% of surviving individuals at a lower rate compared to individuals growing naturally within the nearest TPFL.* |
| *Recruitment of second generation individuals' that are equivalent to recruitment rates of individuals growing naturally within the nearest TPFL.* | *Recruitment of second generation individuals' is less than recruitment rates of individuals growing naturally within the nearest TPFL.* |

*There is currently limited information of survival and establishment rates of this species when grown on a waste landform. Therefore, percentage survival and flower production is significantly lower in comparison to translocated cuttings and seedlings. We do, however, expect that if this species successfully survives and establishes on the waste landform as per other translocation trials using cuttings then it will also flower and show recruitment as a result of being irrigated in the first two years.*

*If there is no survival of the seedlings then this aspect of the translocation trial may be abandoned.*

*Long term criteria (after 5 years)*

*Seed Trials*

| ***Success Criteria*** | ***Failure Criteria*** |
|---|---|
| *Survival rates are equivalent to those D. masonii individuals growing naturally within the nearest TPFL.* | *Survival rates are not equivalent to those D. masonii individuals growing naturally within the nearest TPFL.* |
| *Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL.* | *Flower production and seed set in surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL.* |
| *Recruitment of second generation individuals' that are equivalent to recruitment rates of individuals growing naturally within the nearest TPFL.* | *Recruitment of second generation individuals' is less than recruitment rates of individuals growing naturally within the nearest TPFL.* |

*If long-term criteria for success are met for three consecutive years then the plants in these trials are likely to be self-sustaining and thus concludes the requirements of this Translocation Proposal.*

The notes above regarding abandonment of the trial and investigation of differing treatments is reiterated. Where germination does occur, survival of the seedlings will be monitored as described by Section 2.3.

This work is seeking to determine whether *Darwinia masonii* seeds will germinate on the WRL slopes in the absence of artificial irrigation, with pre-treatment undertaken to replicate the conditions of a natural disturbance, such as a fire and rain event. The nature of the trial is to answer the questions, "will they germinate?", and if so, "at what rates?" The defined success and failure criteria previously proposed for the direct offsets conditioned by MS1045 is not appropriate as long term monitoring is not necessary to understand if the objectives have been met. The work will determine, whether or not the plants germinate and will record the germination and survival rates, initially quarterly for a period of two years and then annually for three years. This information can then be used to determine appropriate seeding rates for any future translocation programs.

It is further noted that the medium term success criteria identified above are not appropriate for plants germinated from seed, given the length of time required for a new plant to produce seed (BGPA 2010 reported 6 years and MGM observations of plant growing in topsoil stockpiles indicate a plant can produce a flower in approximately 4 years). It is also noted that BGPA (2010) reported a natural survival rate for seedlings of 10%.

Based on the above and the information provided by section 2.2, the success criteria proposed will supersede the content of the ATP (and stated above in italics) as follows.

Short term criteria (approx. 2 years, with irrigation)

Seeding Trials

| Success Criteria | Failure Criteria |
|---|---|
| >10% of germinants survive the first two summers. | <10% of germinants survive the first two summers. |

Medium term criteria (2-5 years, without irrigation)

Seeding Trials

| Success Criteria | Failure Criteria |
|---|---|
| ≥average of 1 plant per m2. | ≤average of 1 plant per m2. |

# 3. References

Botanic Gardens and Parks Authority (BGPA) (2010). *Darwinia masonii and Lepidosperma gibsonii Conservation and Restoration Research. An integrated research program into the ex situ and in situ conservation, restoration and translocation requirements of Darwinia masonii and Lepidosperma gibsonii May 2007 – June 2010*. Unpublished report prepared by Botanic Gardens and Parks Authority (Kings Park and Botanic Garden) for Mount Gibson Mining Limited and Extension Hill Pty Ltd, Perth, WA.

Mount Gibson Mining Ltd (2017) Mine Closure Plan, Iron Hill Deposits Hematite Operation.

Mount Gibson Mining Ltd (2018) *Darwinia masonii* Translocation Trial Report 2017 – 2018. March 2018.

# APPENDIX 1 – SUMMARY OF CHANGES TO APPROVED TRANSLOCATION PROPOSAL

| Aspect | Approved Translocation Proposal | Translocation Addendum |
|---|---|---|
| Introduction and Purpose | The purpose of this Proposal is to outline a program to:<br>1. Undertake translocations of D. masonii juveniles from cuttings using proven methodologies developed by BGPA (2010), including using a supplementary watering regime at multiple sites; and<br>2. Undertake experimental translocations of D. masonii seedlings and seeds by building on research outcomes of BGPA (2010).<br>The purpose of the actions is to augment outcomes of the experimental phase of the translocation study (BGPA 2010; Appendix 2) and enact certain requirements of the species' recovery plans. | This addendum is a subset of the approved translocation proposal and is limited to information relevant to the proposed changes.<br>The purpose of the trials is twofold:<br>3) Using key learnings gained by laboratory based germination trials (BGPA 2010), apply the most ideal method of germinating *Darwinia masonii* to field based trials on the Iron Hill WRL in the absence of artificial irrigation; and<br>4) Advance previous translocation trials conducted on the Extension Hill WRL by translocating juvenile cuttings on a larger scale to the Iron Hill WRL and compare the effect of irrigation versus no irrigation.<br>While the overall purpose of the seeding activity described by this addendum do not differ largely from that of the Approved Translocation Proposal (ATP), only the methodology does.<br>The work proposed here for the translocation of juveniles differs from the ATP, as all previous translocations have applied irrigation for the first one or two years post planting.<br>Importantly, the Iron Hill WRL sits within an Approved Development Envelope (Ministerial Statement 1045). The work described by this addendum are not intended to meet requirements of either Ministerial Statement 1045 or Ministerial Statement 753. Rather, the translocations described by this addendum are for research purposes focused on broadscale restoration practices and may be removed at a later date while Ministerial Statement 1045 (MS1045) remains in effect. Upon implementation of the Iron Hill Mine Closure Plan (MGM 2017), the translocations may remain established and no plants would need to be removed. |

| | | |
|---|---|---|
| Translocation Areas | | This addendum includes the Iron Hill WRL as an additional translocation area. The Iron Hill WRL is described in Section 2.1. |
| Seeding Trials | This part of the trial will complement the research of Sebastian Lamoureux B.Sc (UWA PhD Candidate) by building on the outcomes of the research program, by testing the direct sowing of pre-treated, as well as, untreated *D. masonii* seed. Successfully proven dormancy breaking seed pre-treatments include burial and smoke water application (BGPA 2010). The early recommendations from the research program (and associated approved translocation program; Figure 9-A and 9-B) will inform site preparation requirements for these trials. Due to its location within an approved disturbance envelope, Site 10 may be used for trials but not for permanent plots. | Only treated seed included in this activity. All seed will be treated by a period of burial and smoke water prior to seeding and bulked up with soil at 4 parts soil to 1 part seed to aid seed setting within the surface soil. |
| Juvenile Plant Trials | | This amendment includes translocation of juvenile plants to the Iron Hill WRL, a site not included in the ATP.<br><br>This trial proposes to establish six approx. 15m x 15m plots of 100 plants each on the Iron Hill WRL. Three will be irrigated to at least the end of the first summer and three will not be irrigated. Each plot will be no closer than 30m from another plot and the irrigated vs non-irrigated interspersed with each other thereby allowing the plots to expand across a range of the landform. This will build upon the success of the Extension Hill WRL trial and determine if it is possible to translocate juveniles from cuttings to WRL's on a large scale without the assistance of irrigation.<br><br>None of these plants would form part of the direct offsets required by MS1045. |
| Plant source and translocation methodology – Juvenile Plants | Site selection, selection of the origin of cuttings or seeds (dependent on site selection) and potential applications for a Native Vegetation Clearing Permit (NVCP) will occur over the winter periods of 2015 and 2016.<br><br>Ground preparation may be required at translocation sites. Disturbed areas may be ripped to reduce the effects of compaction that may have | The Iron Hill WRL has been added as an additional translocation area.<br><br>This trial proposes to establish six approx. 15m x 15m plots of 100 plants each on the Iron Hill WRL. Three will be irrigated to at least the end of the first summer and three will not be irrigated. Each plot will be no closer than 30m from another plot and the irrigated vs non- |

| | | |
|---|---|---|
| | occurred as a result of their previous use. Translocations into natural areas will not require any site preparation other than digging holes in which to put the cuttings/seedlings.<br><br>*Darwinia masonii* cuttings will be required from *in situ* sources and are in addition to those currently held at the Nuts about Natives nursery. Cuttings and seedlings will be propagated in pots at the Nuts about Natives nursery in Karnup, Western Australia (hygiene-accredited nursery) and transported to Extension Hill mine site at the time of planting. The cuttings/seedlings will then be planted by hand, and placed in previously prepared holes, approximately 0.3 m in depth. A fertiliser (for Australian natives) may be added to supplement the soil in each hole.<br><br>The cuttings/seedlings will be watered in and then drip irrigation will be made available to each plant. Cuttings/seedlings will be irrigated for one hour, twice per month for the first two summers and possibly winter period (if required, due to drought or a very dry preceding or trailing winter period).<br><br>Each plant will be tagged and given a unique identifier that links it back to propagation and source information. | irrigated interspersed with each other thereby allowing the plots to expand across a range of the landform. This will build upon the success of the Extension Hill WRL trial and determine if it is possible to translocate juveniles from cuttings to WRL's on a large scale without the assistance of irrigation. |
| Plant source and translocation methodology – Seeding | Where seeding is conducted, irrigation will be made available to seedlings at the end of the winter period. Seeding will be based on the following assumptions:<br><br>• Seed germination of approximately 90% (following pre-treatments; based on BGPA, 2010 research outcomes),<br><br>• Approximately 10% of seedlings may survive to the end of winter (based on BGPA, 2010 research outcomes),<br><br>• One plant/ 2 $m^2$,<br><br>• Trial area of 100$m^2$ in the first year of the trial.<br><br>On the waste landform and other disturbed areas (e.g. Type B areas), based on outcomes of the UWA translocation research program, more | The treated seed application proposed for the Iron Hill WRL will differ to the above as irrigation will not be applied to seeded areas. The work will examine the viability of seeding as a method of restoration across broader areas to be rehabilitated.<br><br>750g of *Darwinia masonii* seed collected from TPFL 1 (Figure 3) were buried in May 2018. The seed will remain buried for approximately 6 to 9 months, 2cm below the ground surface and then be removed and smoke treated as per BGPA (2010).<br><br>Seed will be spread over 10m x 10m areas plots by hand at a rate of 75g per plot, allowing for up to 10 areas. The seed will be bulked with topsoil at a rate of 4 parts soil to 1 part seed to aid with seed setting into the soil surface. 5 areas will be established immediately after the |

| | | |
|---|---|---|
| | than one trial area with differing soil treatments may be used to determine the success of this methodology. On natural areas, the trial area will be restricted to the one area. This conservative approach builds on D. masonii seed research to-date (i.e. BGPA, 2010) and the outcomes of the UWA D. masonii translocation program.<br><br>The size of the trial area and number of resulting plants may then be supplemented in the following year to meet success criteria (defined in Section 4.6). | WRL is ripped which is anticipated to be around November / December 2018. Another 5 plots will be established in March 2019. This will allow for a comparison between seed which has been buried longer (approximately 9 months compared to approximately 6 months) and is sown in Autumn, and seed that is buried for a shorted period and sown in summer, immediately after ripping of the rehabilitated area. |
| Maintenance and Monitoring | The survival and condition of plants in each trial area (approx. 100 $m^2$) will initially be recorded. Cuttings/seedlings will be monitored weekly for the first eight weeks and spot irrigated if required (subject to rainfall events) to assist with early survival and plant establishment.<br><br>After two months and during the summer period, translocation sites will be visited on a monthly basis by site personnel to monitor and record plant survival for a period of two years, conduct maintenance of irrigation equipment and pumps, check water levels in water tanks and assess for herbivory (and consider using fencing if the plants are at risk of extensive herbivory).<br><br>After two years, irrigation equipment will be removed and D. masonii populations will be monitored on an annual basis for survival and condition for the period of five years after their translocation. Second generation plants will be recorded and tagged if evident and monitored thereafter.<br><br>After five years, monitoring will continue to measure survival, flowering and recruitment on an annual basis until such time that long-term criteria for success have been met for three consecutive years.<br><br>Seed trials will be monitored to meet the criteria for success as per the cuttings/seedlings trials (described above) and as described in the Extension Hill Closure Plan (2015). | The monitoring frequency will be quarterly for the first two years, then reduce to annually for the next three years. Weekly monitoring will not be undertaken. This is due to the potential lack of resources to undertake monitoring as the mining operation may be in a period of care and maintenance or closure. Quarterly monitoring is considered adequate as it will generate sufficient data on the changes throughout seasons and will provide enough data to determine if success criteria are being met. |

<table>
<tr>
<td></td>
<td>Seed trials will be monitored to meet the criteria for success as per the cuttings/seedlings trials (described above) and as described in the Extension Hill Closure Plan (2015).</td>
<td></td>
</tr>
<tr>
<td>Success criteria – Juvenile Plants</td>
<td>
Short Term Criteria (2 years with irrigation)
<table>
<tr><th>Success Criteria</th><th>Failure Criteria</th></tr>
<tr><td>Greater than 200 individuals in each trial area (>70% survival)</td><td>Less than 200 individuals in each trial area (<70% survival)</td></tr>
</table>
If monitoring outcomes reflect that the short-term success criteria have not been met, supplementary plantings of cuttings/seedlings may occur in the following year.
<br><br>
Medium term criteria (2-5 years, without irrigation)
<table>
<tr><th>Success Criteria</th><th>Failure Criteria</th></tr>
<tr><td>Greater than 200 individuals in each trial area (>70% survival).</td><td>Less than 200 individuals in each trial area (<70% survival)</td></tr>
<tr><td>Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL.</td><td>Flower production and seed set of surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL.</td></tr>
<tr><td>Recruitment of second generation individuals' that are equivalent to recruitment rates of individuals growing naturally within the nearest TPFL.</td><td>Recruitment of second generation individuals' is less than recruitment rates of individuals growing naturally within the nearest TPFL.</td></tr>
</table>
</td>
<td>This work provides a comparison between irrigated and un-irrigated translocations to determine survival in the absence of irrigation. The success and failure criteria listed above is not appropriate since this is a comparative assessment, and the plants atop the WRL do not form part of an approved Ministerial Statement offset. The criteria outlined above will continue to be applied, however survival for the non-irrigated plots will be assessed against a 35% short and medium term success criteria as opposed to 70% for irrigated plots. The reduced criteria reflects outcomes of previous research (Ruoss 2013, BGPA 2010) indicating reduced survival in the absence of irrigation. Furthermore, long term monitoring (after 5 years) will not be applied as it is not necessary to meet the objectives of the proposed trial which as stated above is to understand survival of non-irrigated plants.<br><br>The plots will be monitored for survival quarterly during the first two years and then annually for 3 years.<br><br>Should survival of non-irrigated plots be greater than 35% this will present a viable case for broadscale restoration without the extra cost and effort required with irrigation. In the future, beyond the scope of this proposal, a small number of cuttings could be collected from natural populations without risk to those populations and a large number of plants grown from cuttings. For example 3000 – 4000 juvenile plants grown from 1000 cut wildstock "parents" could potentially result in 1200 – 1600 long term surviving plants (assuming 40% survival).</td>
</tr>
</table>

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<td></td>
<td>
Given our learnings of the effects of watering on this species for the first two years, we are expecting flower production and recruitment to occur in this medium term period. However, if there is failure then we will continue to monitor them with the expectation that flower production and recruitment will occur in the longer term.<br><br>
Long term criteria (after 5 years)
<table>
<tr><th>Success Criteria</th><th>Failure Criteria</th></tr>
<tr><td>Survival rates are equivalent to those D. masonii individuals growing naturally within the nearest TPFL.</td><td>Survival rates are not equivalent to those D. masonii individuals growing naturally within the nearest TPFL.</td></tr>
<tr><td>Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL.</td><td>Flower production and seed set in surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL.</td></tr>
<tr><td>Recruitment of second generation individuals' that are equivalent to recruitment rates of the individuals growing naturally within the nearest TPFL.</td><td>Recruitment of second generation individuals' is less than recruitment rates of the individuals growing naturally within the nearest TPFL.</td></tr>
</table>
</td>
<td></td>
</tr>
<tr>
<td>Success criteria - seeding</td>
<td>
Short term criteria (approx. 2 years, with irrigation)<br><br>
Seeding Trials
<table>
<tr><th>Success Criteria</th><th>Failure Criteria</th></tr>
</table>
</td>
<td>The notes above regarding abandonment of the work and investigation of differing treatments is reiterated. Where germination does occur, survival of the juvenile cuttings will be monitored as described by Section 2.3.</td>
</tr>
</table>

| | | |
|---|---|---|
| | *Survival of some individuals in each trial area to inform future seed density requirements.* | *Survival of no individuals in each trial area.* |

*Note that we have not specifically stated a number of individuals for seed trials because no information is currently available to determine what can be expected in comparison to the translocation of cuttings/seedlings. If no germination or survival of seedlings occur in this period then this aspect of the translocation trial may be abandoned or repeated with differing treatments.*

*Medium term criteria (2-5 years, without irrigation)*

*Seeding Trials*

| ***Success Criteria*** | ***Failure Criteria*** |
|---|---|
| *Greater than 35% survival in each trial area.* | *Less than 35% survival in each trial area.* |
| *Flower production and seed set in 25% of surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL.* | *Flower production and seed set in 25% of surviving individuals at a lower rate compared to individuals growing naturally within the nearest TPFL.* |
| *Recruitment of second generation individuals' that are equivalent to recruitment rates of individuals growing naturally within the nearest TPFL.* | *Recruitment of second generation individuals' is less than recruitment rates of individuals growing naturally within the nearest TPFL.* |

This work seeks to determine whether *Darwinia masonii* seeds will germinate on the WRL slopes in the absence of artificial irrigation, with pre-treatment undertaken to replicate the conditions of a natural disturbance, such as a fire. The nature of the work is to answer the questions, will they germinate, and if so, at what rates. The work is located within an approved development envelope. As such, the defined success and failure criteria previously proposed is not appropriate and the work will not contribute to conditioned direct offsets. The work will instead determine, whether or not the plants germinate and will record the germination and survival rates, initially quarterly for a period of two years and annually for a period of three years. This information can then be used to determine appropriate seeding rates for any future translocation programs.

*There is currently limited information of survival and establishment rates of this species when grown on a waste landform. Therefore, percentage survival and flower production is significantly lower in comparison to translocated cuttings and seedlings. We do, however, expect that if this species successfully survives and establishes on the waste landform as per other translocation trials using cuttings then it will also flower and show recruitment as a result of being irrigated in the first two years.*

*<u>If there is no survival of the seedlings then this aspect of the translocation trial may be abandoned</u>*

*Long term criteria (after 5 years)*

*Seed Trials*

| ***Success Criteria*** | ***Failure Criteria*** |
|---|---|
| *Survival rates are equivalent to those D. masonii individuals growing naturally within the nearest TPFL.* | *Survival rates are not equivalent to those D. masonii individuals growing naturally within the nearest TPFL.* |
| *Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL.* | *Flower production and seed set in surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL.* |

| | | |
|---|---|---|
| | *Recruitment of second generation individuals' that are equivalent to recruitment rates of individuals growing naturally within the nearest TPFL.* | *Recruitment of second generation individuals' is less than recruitment rates of individuals growing naturally within the nearest TPFL.* |
| | *If long-term criteria for success are met for three consecutive years then the plants in these trials are likely to be self-sustaining and thus concludes the requirements of this Translocation Proposal.* | |

Government of **Western Australia**
Department of **Parks and Wildlife**

# Translocation Proposal Approval

TAXON: D*arwinia masonii* (Feb 2016)

Proponent(s):

Mount Gibson Mining Limited
Level 1, 2 Kings Park Road
West Perth WA 6005

Extension Hill Pty Ltd
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## APPROVAL

DIRECTOR OF SCIENCE AND CONSERVATION: MARGARET BYRNE.

Approved by (signature): Margaret Byrne

Date: 17/5/16

# MOUNT GIBSON MINING LIMITED

# PROPOSAL FOR THE TRANSLOCATION OF DARWINIA MASONII

**Version 4**
**Date of Revision: May 2016**

**Mount Gibson Mining Limited**
ABN 32 074 575 885

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## TABLE OF CONTENTS

**1. Introduction ..... 1**
**1.1 Species recovery actions ..... 1**
**1.2 Purpose of Proposal ..... 2**
**1.3 Evidence of Current Translocation Success ..... 2**
**1.4 Proponents ..... 4**
**2. Background ..... 5**
**2.1 Description ..... 5**
**2.2 Biology ..... 5**
2.2.1 General ecology ..... 5
2.2.2 Seed germination and fire ecology ..... 6
**2.3 Conservation status ..... 7**
**2.4 Population size and distribution ..... 7**
**2.5 Research to date ..... 8**
**2.6 Translocation commitments ..... 9**
**3. Translocation Proposal ..... 11**
**3.1 Site selection considerations ..... 11**
3.1.1 Suitable habitat ..... 11
3.1.2 Logistics of providing supplementary water ..... 15
3.1.3 Source and availability of live plant material ..... 15
3.1.4 Prospective exploration and mining areas ..... 17
**3.2 Translocation areas ..... 18**
**3.3 Translocation timelines ..... 21**
**3.4 Plant Source and Translocation methodology ..... 22**
**3.5 Maintenance and monitoring ..... 23**
**3.6 Criteria for success ..... 24**
3.6.1 Short term criteria (approx. 2 years, with irrigation) ..... 24
3.6.2 Medium term criteria (2-5 years, without irrigation) ..... 24
3.6.3 Long term criteria (after 5 years) ..... 25
**3.7 Reporting ..... 26**
**3.8 Funding ..... 26**
**4. Endorsement ..... 27**
**5. References ..... 28**
**6. Appendices ..... 30**
Appendix 1 - *Darwinia masonii* Draft Recovery Pan (DPaW 2015) ..... 31
Appendix 2 *Darwinia masonii* Conservation and Restoration Research Report ..... 32

## List of Figures

FIGURE 1 *DARWINIA MASONII* TRANSLOCATION TRIAL AREA: TRANSLOCATED *D. MASONII* FROM GREEN-STOCK CUTTINGS WITH INDIVIDUALS RECORDED AS HEALTHY AND FLOWERING (A; 2014), *D. MASONII* SEEDLINGS RECORDED DIRECTLY OUTSIDE OF THE TRANSLOCATION PLOT FENCE (B AND C; 2014). ..... 3

FIGURE 2 PREDICTED HABITAT OF *D. MASONII* (RED OUTLINE) IN RELATION TO SLOPE > $12^{O}$ (ORANGE), ELEVATION (340, 360 AND 385 M AHD SHOWN) AND GEOLOGY (WHITE = GEOLOGY NOT PROSPECTIVE FOR PLANTS BUT OTHER COLOURED AREAS RATED > 60% PROBABILITY) (ADAPTED FROM BGPA, 2010). ..... 11

FIGURE 3 "HEAT" MAP STYLIZATION SHOWING RELATIVE DENSITY OF WILDSTOCK *D. MASONII* ON MOUNT GIBSON RANGES (THE CLUSTER AT IRON HILL EAST TRANSLOCATION TRIAL PLOT IS HIGHLIGHTED). ..... 12

FIGURE 4 POTENTIAL TRANSLOCATION SITES (1-10) OVERLAID ON ACTUAL RECENT *D. MASONII* DISTRIBUTION PER FIGURE 2 (ECO LOGICAL 2014).A NOMINAL 500M BUFFER IS SHOWN WITH PREDICTED HABITAT (BGPA, 2010) WITH CORRELATION EVIDENT BETWEEN RECORDS AND PREDICTED HABITAT..... 13

FIGURE 5 *DARWINIA MASONII* DISTRIBUTION WITH GENERAL LOCATION NAMES AND NOMINAL BOUNDARIES (50M BUFFER) FOR THE ASSIGNED THREATENED AND PRIORITY FLORA DATABASE (TPFL) NUMBER..... 14

FIGURE 6 ORIGINAL TRANSLOCATION TRIAL (A) AND A PREVIOUSLY DISTURBED AREA ADJACENT TO THE TRIAL AREA (B) SUITABLE FOR SUPPLEMENTARY PLANTINGS. ..... 18

FIGURE 7 TRACK (A) AND DRILL PAD (B) AREAS (FIGURE 3; AREA 2)..... 19

FIGURE 8 POTENTIAL TRANSLOCATION AREAS WITHIN A MOSAIC OF VEGETATION AND BARE GROUND (A; FIGURE 4; B; FIGURE 4; AREA 5)..... 19

FIGURE 9 UWA REHABILITATION TRIAL AREA ON THE EXTENSION HILL WASTE LANDFORM..... 20

## LIST OF TABLES

TABLE 1 SUMMARY OF *DARWINIA MASONII* POPULATION INFORMATION ON THE MT GIBSON RANGES. ..... 8

TABLE 2 CHARACTERISTICS OF EACH POTENTIAL TRANSLOCATION SITE (1-10) WITH TYPE OF AREA IN BRACKETS: COORDINATES USING THE MAP GRID OF AUSTRALIA (MGA) ZONE 50, ELEVATION, AVERAGE SLOPE, ASPECT AND SUBSTRATE DESCRIPTION. ..... 15

TABLE 3 SUMMARY OF *DARWINIA MASONII* CUTTINGS HELD AT NUTS ABOUT NATIVES AS OF DECEMBER, 2015. ..... 16

TABLE 4 RECORDS OF *DARWINIA MASONII* SEED COLLECTIONS. ..... 17

TABLE 5 NOMINAL TIMELINE FOR TRANSLOCATION ACTIVITIES ..... 22

# 1. Introduction

*Darwinia masonii* is one of 65 Western Australian species in the genus. *Darwinia masonii* is found within the Mt Gibson Ranges, 350 km north-east of Perth. *Darwinia masonii* is predominantly restricted in its distribution to the upper slopes, crests and ridges of all the hills and most of the slopes that comprise the length of the 6 km range. It is specially protected under the Western Australian *Wildlife Conservation Act 1950* and is ranked as Vulnerable (VU) in Western Australia under International Union for Conservation of Nature (IUCN) 2001 Red List criterion D2. The species is also declared as 'Vulnerable' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

## *1.1 Species recovery actions*

Mount Gibson Mining (MGX) has been mining on Extension Hill at the Mt Gibson Ranges since 2010. Prior to this time, MGX and Extension Hill Pty Ltd (EHPL) went through an extensive formal Environmental Impact Assessment (EIA) via Part IV of the *Environmental Protection Act 1986* (WA) and after referral under Section 68 of the EPBC Act. Ministerial Statement No 753 (MS 753) was granted in October of 2007. EPBC Act Approval was granted in December 2007 (EPBC 2005/2381).

Condition 6-1 (4) of MS753 (http://www.asiairon.com.au/Portals/0/Docs/10-905-EN-REP-0004_3%20-Approval%20753.pdf) requires that the proponent **develop** "*measures to offset the direct impacts of the proposal on the local population of* Darwinia masonii *by regeneration, re-establishment or translocation of additional plants or sub-populations on suitable un-impacted areas of banded ironstone formations in the Mt Gibson area.*" Aspects of this proposal serve that conditioned requirement.

The draft Recovery Plan developed by MGM and EHPL (in consultation with Parks and Wildlife) also builds on the actions of the Interim Recovery Plan (http://www.mtgibsoniron.com.au/wp-content/uploads/2012/12/Darwinia-Masonii-Interim-Recovery-Plan-2008-2012.pdf) with a specific recovery action to "*prepare and implement a restoration program*".

The Draft Recovery Plan (Parks and Wildlife, issued: August 2014; Appendix 1) also describes the actions and tasks to develop and implement a restoration program, thus:

> "*The knowledge gained from the habitat modelling (BGPA, 2010) and translocation trials, which have already been conducted (BGPA, 2010) will assist in identifying suitable habitat for Darwinia masonii translocations, both in suitable areas of the Mt Gibson Range, other suitable habitat, and in the rehabilitation of areas disturbed by mining.*
>
> *Future translocations should consider an allowance for irrigation of translocated plantings as this will increase the translocation success rate.*
>
> *Propagation of live plant material from wild collections and nursery stock are likely the most cost effective approach for the short-medium term production of plants for restoration purposes. Seed germination and seedling establishment under glasshouse or field conditions may also provide an approach for a genetically diverse and numerous sources of restoration plants (BGPA, 2010).*"

## 1.2 Purpose of Proposal

The purpose of this Proposal is to outline a program to:

1. Undertake translocations of D. masonii juveniles from cuttings using proven methodologies developed by BGPA (2010), including using a supplementary watering regime at multiple sites; and
2. Undertake experimental translocations of D. masonii seedlings and seeds by building on research outcomes of BGPA (2010).

The purpose of the actions is to augment outcomes of the experimental phase of the translocation study (BGPA 2010; Appendix 2) and enact certain requirements of the species' recovery plans.

This Proposal provides the level of information and format defined in Parks and Wildlife's Corporate Policy Statement No. 35 *Conserving Threatened Species and Ecological Communities* (2015a) and Corporate Guideline No. 36 *Recovery of Threatened Species through Translocation and Captive Breeding or Propagation* (2015b), and taking into account the Australian Network for Plant Conservation translocation guidelines (Vallee *et al.* 2004) and IUCN Guidelines for Reintroductions and Other Conservation Translocations (2013).

## 1.3 Evidence of Current Translocation Success

A translocation trial of 206 *D. masonii* plants (BGPA 2010) has been considered a success (Figure 1A): An 83.5% survival rate after nine years (2005-2014) within irrigated fenced plots (irrigated for the first two years, but not after), and with 90% of individuals recorded as reproductive in 2013 (pers. com. J Sackmann, March 2014). Numerous seedlings were also recorded immediately surrounding the trial plot (Figure 1B and C), which additionally confirm the translocated individuals have reached reproductive maturity and produce viable seed. Note that there is also a small possibility that the observed seedlings have germinated from the seedbank that may have been derived from a population that was previously there prior to disturbance and the establishment of the translocated plants.

There were also 20 additional *D. masonii* plants that were planted outside of the fenced, irrigated area. While the sample number was low, the survival rate of these plants was recorded in 2010 as only 10% in comparison to 89% for those that had been irrigated and fenced.

Other translocation trials were conducted testing survival and establishment success on different substrates (without irrigation): rock, gravel, sand and clay (BGPA 2010; Ruoss 2013). Nine months after planting, *D. masonii* plants did not survive on clay or sand substrates (BGPA 2010). Plant survival rates (from 65 plants/plot and 3 plots/substrate) of 25 and 38% were recorded on the gravel and rock substrates, respectively (BGPA 2010).

**Figure 1 *Darwinia masonii* translocation trial area (2005): Translocated *D. masonii* from green-stock cuttings with individuals recorded as healthy and flowering (A; 2014), *D. masonii* seedlings recorded directly outside of the translocation plot fence (B and C; 2014).**

## 1.4 Proponents

The proponents for this Proposal are:

Mount Gibson Mining Limited (ACN 074 575 885); and Extension Hill Pty Ltd (ACN 067 128 938)

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# 2. Background

## 2.1 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 et al., 1998).

*Darwinia masonii* has a known annual flowering period from April to November (Brown *et al.*, 1998). As the rainfall in the region is unreliable, *D. masonii* appears to respond opportunistically to rainfall events (i.e. tropically influenced summer rainfall events and southern winter cold fronts). Strong vegetative growth (but not reproductive stages) has been observed following summer rainfall events.

## 2.2 Biology

### 2.2.1 General ecology

Mature plants of *D. masonii* have a slow, irregular and modular growth form (BGPA, 2010). Seedling growth forms are more regular with increases in height and stem diameter correlated with age. Older plants may show 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 a presence or absence of spongy bark. Individuals may be prostrate or reclining, and the canopy is not uniform in shape.

Flowering of young plants begins to occur at six years (BGPA, 2010), however, observations of propagated cuttings produce flowers under nursery conditions within one year since striking (pers. comm. B. Croxford, 2016). Flower numbers are greater for old plants with wide canopies. Flower heads form on the terminal end of branches and new vegetative shoots are produced laterally from below the terminal flowering head. Plants have been recorded flowering between April and November (Brown *et al.*, 1998). In 2009, the Botanic Gardens and Parks Authority (BGPA) recorded flowers opening between late August and late October (BGPA, 2010).

*Darwinia masonii* is identified as pollinated by birds, with a brief study recording pollination by the White-fronted Honeyeater (*Phylidonyris albifrons*) (BGPA, 2010). *Darwinia masonii* is capable of producing low-viability, self-pollinated (selfed) seed, but the production of outcrossed seed is a critical requirement for self-sustaining populations, as there was weak evidence that selfed seed were less fit than outcrossed seed.

*Darwinia masonii* seed production is moderately low, with between 15% and 30% of developed fruits in an infructescence containing filled seed (BGPA, 2010). The mean number of filled seeds per infructescence in BGPA's study (2010) was 2 to 4.5 and, on average, between 25 and 75 filled seeds were produced per flowering plant. Seed production takes place in spring and early summer with the peak of ripe seed production occurring around mid-November in 2009 (BGPA,

2010). The peak period for seed collection depends on the relative rates of seed development and seed drop and may vary between years and localities. Seed dispersal occurs by ants.

BGPA (2010) reported that "While mortality is rare among mature *D. masonii* plants, drought over the winter of 2010 contributed to a significant level of mortality (>10% in one site)" (p6).

There is significant spatial and temporal variation in mortality of *D. masonii* seedlings (BGPA, 2010). The death rate for seedlings monitored between 2007 and 2009 in five plots last burnt in 2003 ranged from 2.5% to 15% per year. Possible reasons for the variation in seedling mortality included seasonal variation in rainfall, soil water holding capacity and the microclimate of the plots. BGPA suggested that low survival of *D. masonii* seedlings (9%) in plots within an experimental burn may partly have been attributed to the drought over the dry winter of 2010.

*Darwinia masonii* shares with co-occurring species, the drought avoiding strategy of closing down transpiration and photosynthetic function to enter a period of physiological dormancy through drought, with the capacity to restore tissues as soils wet (BGPA, 2010).

Roots of *D. masonii* have a capacity to enter large cracks, pores and fissures in regolith and may achieve considerable root depths (BGPA, 2010). *Darwinia masonii* also has a clear association with Vesicular-Arbuscular Mycorrhizae (VAM) (BGPA, 2010). These attributes likely assist the species to persist in environments with low water and nutrient availability.

In relation to grazing, the *Darwinia masonii* Interim Recovery Plan (IRP) (DEC, 2008) stated that "only very minor grazing pressure from feral goats and rabbits of *D. masonii* has been observed to date". However, BGPA (2010) found that grazing by vertebrates (presumed to be goats and rabbits) had no impact on *D. masonii*. Grazing is, however, considered to be a potential threat and is monitored with suitable mitigation measures, such as fencing, to be implemented if it poses a real threat (*Darwinia masonii* Draft Recovery Plan, 2015).

The impact of termites has not appeared to be significant on the mean growth rates and health scores of *D. masonii* (BGPA, 2010). Foliar loss or damage by insect attack was only noted in the form of galls on a very small number of *D. masonii* individuals (BGPA, 2010). Insect attack is thus not considered to be a significant threat to the species.

Modelling of species distributions against spatially mapped environmental data found that the principal environmental parameters predicting the distribution of *D. masonii* were slopes over 7-8°, elevation over 380m AHD and all geology types within the Mt Gibson Ranges except "White Rock (unclassified, including granite and its group, acidic dyke rocks, feldspar porphyry and meta-sediments phyllitic rock)" (BGPA, 2010). However, many areas in the Mt Gibson Ranges where populations were most highly predicted to occur by the modelling do not support *D. masonii*. BGPA concluded that the distribution of *D. masonii* may have an association with unmapped sub-surface features such as regolith (soil depth, underlying rock structure) and longer-term (prior to the 1960s) fire history patterns.

### 2.2.2 Seed germination and fire ecology

Large scale production of seedlings of *D. masonii* via germination of fresh or stored seed involves physical manipulation of small seeds for seed coat nicking or removal, or retrieval of seed buried for months or years (BGPA, 2010). Seed of *D. masonii* has physical and physiological dormancy (removal/breakdown of fruit walls and stimulatory effect of smoke chemicals, respectively). 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. Germination rates of 90% were achieved with filled seed exhumed after 9 months of burial and treated with smoke water.

There is evidence of limited inter-fire recruitment of *D. masonii* in older populations. *Darwinia masonii* is long-lived and killed by fire (Armstrong and Associates, 2004; BGPA, 2010). Plants arising from seed germinate in a single cohort post-fire. A wildfire burnt out a significant area in southern and eastern portions of the Ranges in January 2003. None of the *D. masonii* plants burnt during that fire survived during the spring of 2003 (Armstrong and Associates 2004).

There is also evidence of limited post-fire recruitment of *D. masonii* in older populations (BGPA, 2010). Plant sizes from data collected in 2007 during BGPA's demographic study ranged in height up to 240 cm and 2.5 m in canopy width. The largest stem diameter was 74 mm. Plant size correlated with population age in frequency distribution graphs of the young (last burnt in 2003) and mature (last burnt in 1969) plots, which showed distinct peaks in size and a narrow size range. The older (last burnt before 1968) plots were estimated to have been unburnt for over 85 years and had the oldest and largest plants in them. However, the frequency distribution graphs did not have distinct peaks in size, but rather a spread of plant sizes. The data from the older plots confirmed that *D. masonii* is long-lived and that limited recruitment occurs at infrequent intervals in the absence of fire.

Regeneration after fire is restricted exclusively to germination from seed held in long-lived soil-stored seedbanks (BGPA, 2010). Recruitment in plots within the boundary of an experimental fire conducted by BGPA in May 2009 confirmed that *D. masonii* germinates strongly after fire, with a seedling density in burnt areas of 1.2/$m^2$ and 3.2 seedlings per pre-fire adult (BGPA, 2010). The fire on 12 May 2009 was not as intense as anticipated and was patchy, such that 73 of the 93 pre-fire adults were burnt. However, it achieved what was intended i.e. the fire killed the canopy; there was a good amount of ash produced; and, seedlings emerged afterwards. Soil temperature at some of the probe sites did reach 250°C (B Miller 2013, pers. comm., 17 December). 233 seedlings were counted within the area burnt in the experimental fire plots, in comparison to recruitment of only one seedling in the 15 unburnt plots over the course of the study (May 2007 to June 2010). This seedling was recorded in an older (pre-1968) plot on Mt Gibson South in July 2009. This corroborates with findings of BGPA's population structure study - that post-fire recruitment is limited in older populations but does occur.

## 2.3 Conservation status

*Darwinia masonii* is specially protected under the Western Australian *Wildlife Conservation Act 1950* and is ranked as Vulnerable (VU) in Western Australia under the International Union for Conservation of Nature (IUCN) 2001 Red List criterion D2. Furthermore, *D. masonii* is listed as Vulnerable under the Commonwealth EPBC Act as of July 2000.

## 2.4 Population size and distribution

*Darwinia masonii* has only been recorded within the Mt Gibson Ranges, 350 km north-east of Perth. *Darwinia masonii* is predominantly restricted in its distribution to the upper slopes, crests and ridges of the eleven major hills that comprise the 6 km range.

The most recent census by Eco Logical Australia (2014; Table 1) of the *D. masonii* population found 20,965 individuals comprising of 19,132 mature individuals, 1,580 juveniles, 188 seedlings and 65 senescent individuals. This does not include the 1,702 individuals removed by the existing mining operations to-date. Eco Logical Australia (2014) concluded that the population was healthy based on the relatively high proportion and spatial distribution of plants with flowering and fruiting material, and the low proportion of senescent plants.

**Table 1 Summary of *Darwinia masonii* population information on the Mt Gibson Ranges.**

| TPFL Pop No. | Broad location description | Take status | Date of most accurate monitoring record | Number of plants Eco Logical (2014) | Tenure |
|---|---|---|---|---|---|
| **1** | Iron Hill South | Extant | 11-17/06/2014 | 488 | Crown reserve, mining lease |
| **2** | Extension Hill | Partially taken - hematite pit | 11-17/06/2014 | 1,876 | Unallocated crown land, mining and pastoral leases |
| **3** | Extension Hill North | Taken | 19/07/2004 (estimate) Present | 0 | Mining and pastoral leases |
| **4** | Extension Hill South | Extant | 11-17/06/2014 | 2,082 | Unallocated crown land, mining lease |
| **5A, 5B** | Iron Hill East | Extant | 11-17/06/2014 | 1,669 | Crown reserve, mining lease |
| **6A, 6B, 6C** | Mt Gibson | Extant | 11-17/06/2014 | 9,761 | Unallocated crown land, crown reserve, mining lease |
| **7** | Mt Gibson South | Extant | 11-17/06/2014 | 883 | Crown reserve, mining lease |
| **8** | Iron Hill | Extant | 11-17/06/2014 | 1,653 | Unallocated crown land, crown reserve, mining lease |
| **9** | Iron Hill North | Extant | 11-17/06/2014 | 1,950 | Crown reserve, mining lease |
| **10** | E of Extension Hill South (~450m SE of TPFL pop 2) | Not taken | 11-17/06/2014 | 587 | Unallocated crown land, mining and pastoral leases |

## 2.5 Research to date

An extensive research program was conducted by Botanic Parks and Gardens Authority (and funded by MGM and EHPL) between 2007 and 2010 (BGPA, 2010; Appendix 2). The program focussed on seven broad research aspects:

1. Conservation genetics: Population structure, comparison with other species, phylogeny and clonality.
2. Population demography: Fire, demography, tools for monitoring plant demographic changes.
3. Breeding/recruitment biology: Seed research, seed production, soil seed bank, phenology, genetic analysis of breeding systems and dispersal.
4. Population Viability Analysis: Modelling of population persistence.

5. Environmental interactions and plant health: Biotic and abiotic associations, habitat requirement assessment, ecophysiology, impacts of associations on plant health, and tools to monitor plant health.
6. **Restoration and translocation**: Reconstruction of habitat, propagation, translocations, and tools to monitor rehabilitation, dust, and water table lowering.
7. Ex-situ conservation propagation for long-term seed storage, and cryostorage.

Specific to the focus of this proposal, the findings of a translocation study (Research aspect 6 above) was summarised by BGPA as follows:

> "*A pilot translocation trial was installed in May 2005 on a ripped drill pad on Iron Hill East. In this trial, 206* Darwinia masonii *cuttings were planted in a grid connected to a drip feed irrigation system, which supplied water for an hour at a time, twice a month over the first two summers. The irrigated plants were fenced to exclude herbivores. Twenty additional plants were planted outside of the fenced and irrigated area. Ten percent of the unwatered plants survived to 2010, while 89% of the watered plants survived. The surviving irrigated plants have grown rapidly to a large size (and tripling in size in their last 18 months) and have flowered extensively and precociously (with half flowering in the first year)*" (BGPA, 2010).

A doctoral thesis (Ruoss 2013) complements the BGPA (2010) research findings with an assessment of the soil seed bank and further assessment of soil composition and its role in restoration success using *D. masonii*. Ruoss (2013) found that the successful establishment of *D. masonii* seedlings required gravelly or rocky substrates with low levels of success occurring when seedlings were grown in sand or loam substrates.

## 2.6 Translocation commitments

Condition 6-1 (4) of MS753 requires that the proponent develop:

"*measures to offset the direct impacts of the proposal on the local population of* Darwinia masonii *by regeneration, re-establishment or translocation of additional plants or sub-populations on suitable un-impacted areas of banded ironstone formations in the Mt Gibson area.*"

This proposal, in-part, serves that conditioned requirement.

Recovery Action #7 in the Interim Recovery Plan (2008 – 2012; Appendix 1) is "*to undertake translocations as part of the Research Program*". This has occurred and outcomes are summarised in Section 3.5. The Interim Recovery Plan remains in place until the (full) Recovery Plan is approved by the CEO as authorised by MS753.

The draft Recovery Plan developed by MGM (in consultation with Parks and Wildlife) also builds on the actions of the Interim Recovery Plan with a specific recovery action to "*prepare and implement a restoration program*".

The Draft Recovery Plan describes the actions and tasks to develop and implement a restoration program, thus:

> "*The knowledge gained from the habitat modelling (BGPA, 2010) and translocation trials, which have already been conducted (BGPA, 2010) will assist in identifying suitable habitat*

*for Darwinia masonii translocations, both in suitable areas of the Mt Gibson Range, other suitable habitat, and in the rehabilitation of areas disturbed by mining.*

*Future translocations should consider an allowance for irrigation of translocated plantings as this will increase the translocation success rate.*

*Propagation of live plant material from wild collections and nursery stock are likely the most cost effective approach for the short-medium term production of plants for restoration purposes. Seed germination and seedling establishment under glasshouse or field conditions may also provide an approach for a genetically diverse and numerous sources of restoration plants (BGPA, 2010)."*

# 3. Translocation Proposal

The proposal is based on taking plant material, propagating them under nursery conditions and establishing them in trial plots on suitable habitat and rehabilitation areas.

## *3.1 Site selection considerations*

Exact locations of translocation sites have not yet been selected; however sites would preferentially be located nearby to sourced material. DPaW is to be consulted on site selection prior to translocation of nursery material into the field, and DPaW Species and Communities Branch is to be contacted for endorsement of the chosen sites.

MGM will identify preferred sites, taking into consideration the following variables:

1. Suitable habitat and potential rehabilitation areas
2. Logistical access of providing supplementary water to plant material used in trial plots
3. Source and use of live plant material including cuttings
4. Longevity of land use

### 3.1.1 Suitable habitat

BGPA (2010) research identified the most suitable habitat for *D. masonii* to be ridges and slopes, with the following characteristics, each showing a probability of *D. masonii* presence of 50-60% when considered on its own:

- Slope of > 7-8°
- Elevation > 380 m
- All geology types except those outside the range (in white; Figure 2).

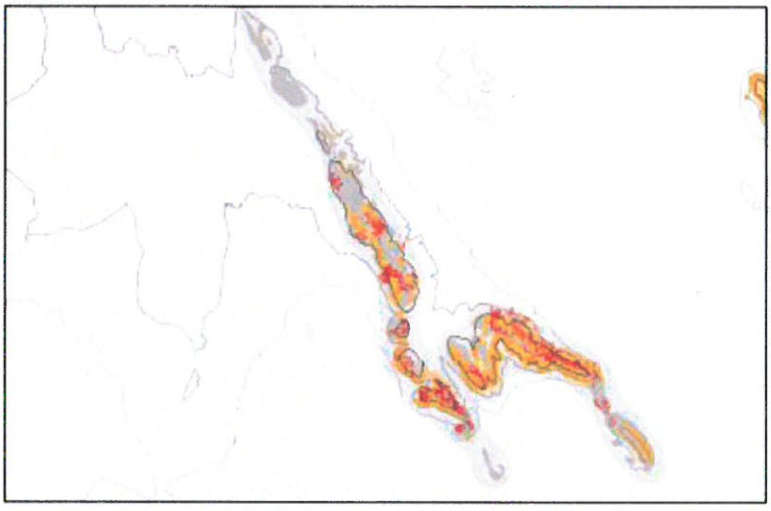

**Figure 2 Predicted habitat of *D. masonii* (red outline) in relation to slope > 12° (orange), elevation (340, 360 and 385 m AHD shown) and geology (white = geology not prospective for plants but other coloured areas rated > 60% probability) (adapted from BGPA, 2010).**

The recent survey work of Eco Logical (2014) shows the actual known area of occupancy of specimens on the Mount Gibson Ranges (Figure 3). The combination of these two mapped areas gives a zone of potential habitat, which is likely to have the greatest success for future translocations of *D. masonii* (Figure 4).

Also shown on Figure 4 are a set of newly proposed translocation trial areas that have potential as future translocation sites. In addition, translocation sites would be on other suitable land (Figure 4). A control site (Type D areas in Section 3.2 below) has also been chosen that does not reflect suitable habitat, other than a gravelly substrate and similar plant community (Figure 4, Site # 6). For reference, Figure 5 shows the *D. masonii* distribution, general location names and the assigned Threatened and Priority Flora database (TPFL) number.

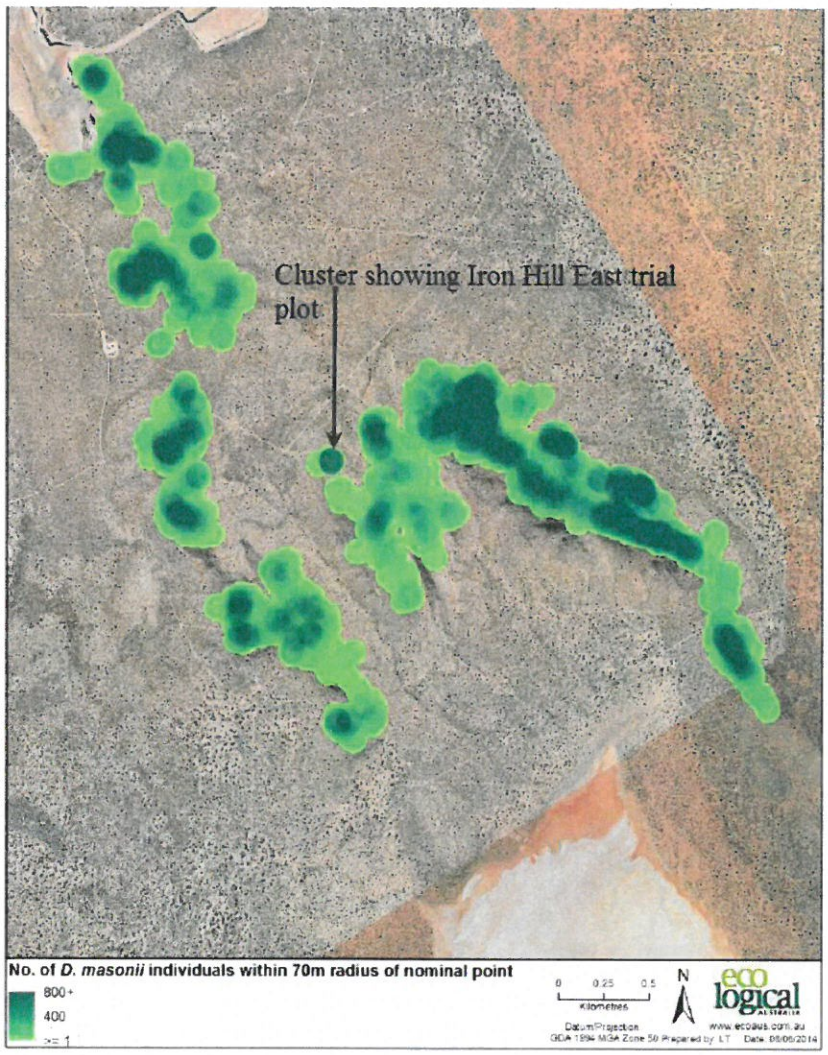


**Figure 3 "Heat" map stylization showing relative density of wildstock *D. masonii* on Mt Gibson Ranges (the cluster at Iron Hill East translocation trial plot is highlighted).**

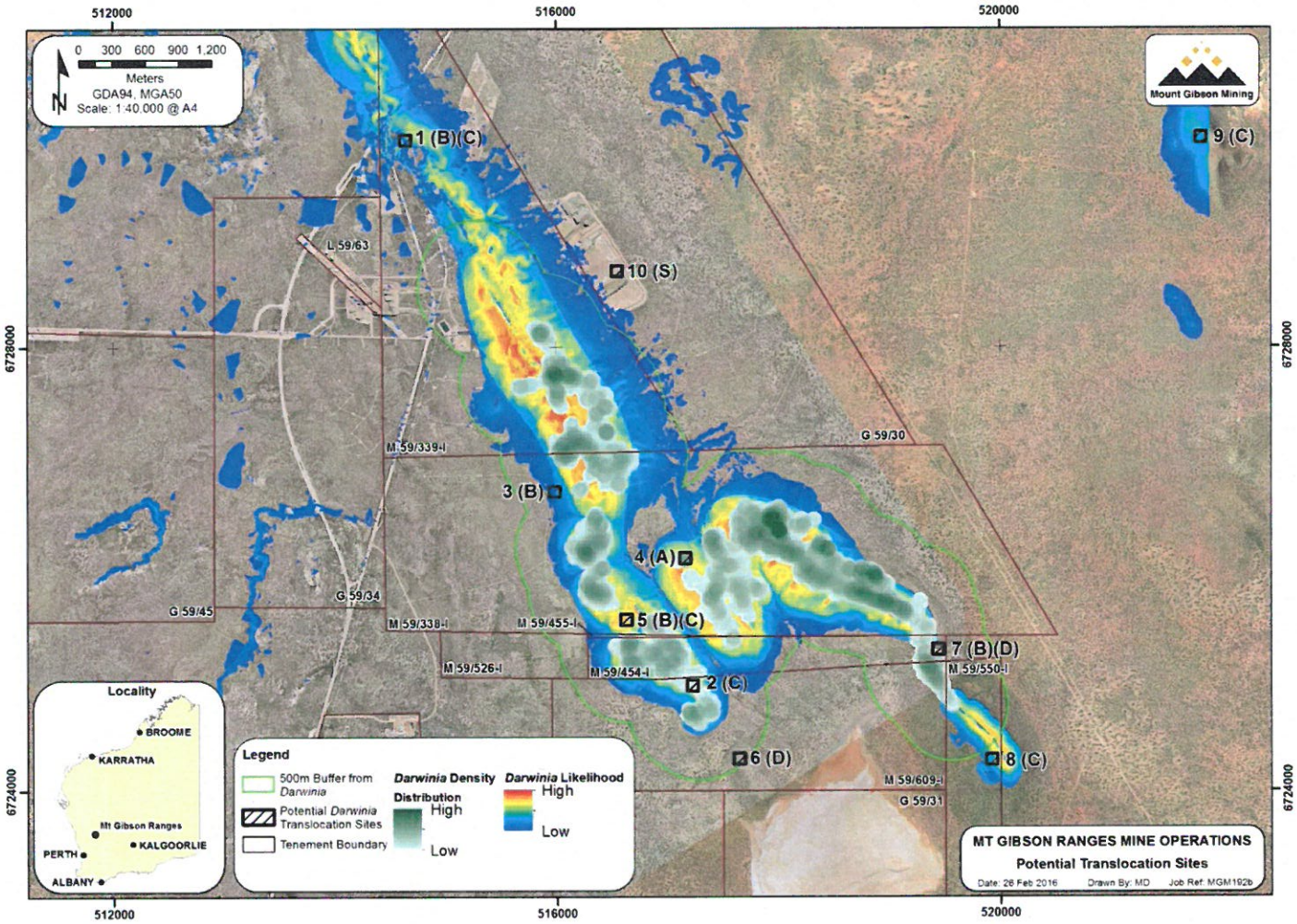


**Figure 4 Potential translocation sites (1-10) overlaid on actual recent *D. masonii* distribution per Figure 2 (Eco Logical 2014). A nominal 500m buffer is shown with predicted habitat (BGPA, 2010) with correlation evident between records and predicted habitat.**

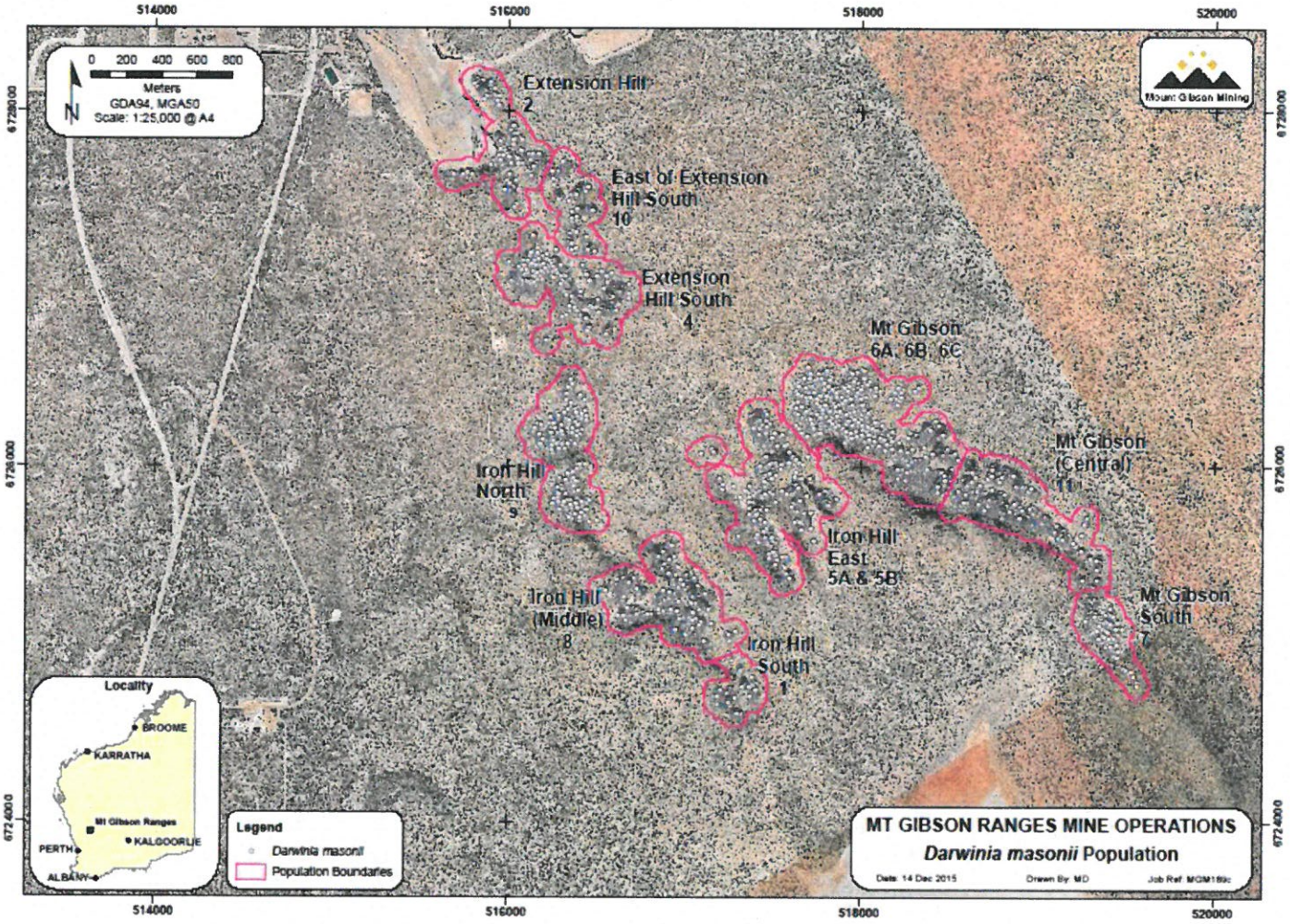


**Figure 5 *Darwinia masonii* distribution with general location names and nominal boundaries (50m buffer) for the assigned Threatened and Priority Flora database (TPFL) number.**

The characteristics of each potential translocation site (1-10) provided in this document as an example of the types of suitable locations, as discussed further in Section 3.2 (Table 2).

**Table 2 Characteristics of each potential translocation site (1-10) with Type of area (see Section 3.2) in brackets: Coordinates using the Map Grid of Australia (MGA) zone 50, elevation, average slope, aspect and substrate description.**

| Site ID | X_MGA50 | Y_MGA50 | Elevation (m) | Slope (°) | Aspect | Description |
|---|---|---|---|---|---|---|
| **1 (B)(C)** | 514640.5 | 6729869 | 375 | 2.3 | Northwest | Breccia ore, only hematite debris cemented by limonitic material |
| **2 (C)** | 517222 | 6724952 | 376 | 9.8 | Southeast | Meta-sediments (Reddish brown phyllite rock) |
| **3 (B)** | 515980.5 | 6726694 | 347 | 4.3 | West | Scree, includes weathered greenstones |
| **4 (A)** | 517276.6 | 6726095 | 386 | 6.4 | North | Scree, includes weathered greenstones |
| **5 (B)(C)** | 516628.2 | 6725546 | 387 | 13.2 | Southeast | Ferruginous cherts (with very few thin bands of hematite) |
| **6 (D)** | 517644.2 | 6724291 | 329 | 3.7 | North | Jaspilite |
| **7 (B) (D)** | 519434.9 | 6725275 | 333 | 3.9 | Southeast | Breccia ore, only hematite debris cemented by limonitic material |
| **8 (C)** | 519919.5 | 6724280 | 348 | 12.7 | Southwest | Scree, includes weathered greenstones |
| **9 (C)** | 521811 | 6729888 | 401 | 12.4 | Southwest | Scree, includes weathered greenstones |
| **10 (S)*** | 516686.6 | 6728600 | 333 | 1.7 | Northeast | Mined debris and waste rock landform comprised of mined rock |

*note these sites are within the approved development envelope and may not be used depending on timing of approved magnetite mining.

### 3.1.2 Logistics of providing supplementary water

The logistics of being able to get water to the translocation site will be closely considered. Steep and narrow tracks or areas of distance from a track make the accessibility of getting water tanks and cartage to an area difficult. In consultation with mine site personnel, the logistics and accessibility will be taken into consideration.

### 3.1.3 Source and availability of live plant material

The individuals from which cuttings would be sourced (and in stock at Nuts about Natives nursery; accredited under the Nursery Industry Accreditation Scheme Australia (NIASA) will be taken into account when determining the location of the area in which to transplant them. Cuttings will be preferentially and initially sourced from Extension Hill (TPFL 2) and Iron Hill (TPFL 1; 8).

The stock at Nuts about Natives nursery have recently been supplemented with additional cuttings collected in September and October under a Permit to Take Declared Rare Flora (Permit No: 28-1516). Stock currently at the nursery are summarised in Table 3. There are also an additional 1,098 cuttings from 26 genotypes collected in July, 2015 from plants growing on topsoil stockpiles from the surface of the Extension Hill/Extension Hill North pit (TPFLs # 2 & 3).

**Table 3 Summary of *Darwinia masonii* cuttings held at Nuts about Natives nursery as of February, 2016.**

| Nursery Code | TPFL | Date struck | Total # genotypes collected | Total # genotypes with roots (Feb, 2016) | Total # clones with roots (Feb, 2016) |
|---|---|---|---|---|---|
| MGMD | 2 | Oct, '08 | 301 | 56 | 239 |
| INB | 8 | 18-21 Sep '15 | 180 | 75 | 184 |
| IND | 8 | 2-4 Oct, '15 | 98 | 71 | 367 |
| INF | 8 | 4-6 Oct, '15 | 239 | 131 | 426 |
| INA | 8 | 6 Oct, '15 | 83 | 20 | 45 |
| ISB | 1 | 15 & 18 Sept '15 | 66 | 31 | 118 |
| ISC | 1 | 1 Oct, '15 | 102 | 52 | 126 |
| ISD | 1 | 1-2 Oct, '15 | 70 | 45 | 184 |
| EHA | 2 | 21-22 Oct, '15 | 204 | 75 | 155 |
| EHB | 2 | 23-24 Oct, '15 | 76 | 36 | 142 |
| EHE | 2 | 24-25 Oct, 2015 | 44 | 19 | 45 |

Seed material, previously collected (Table 4), may be used following initial trials to determine germination and survivorship requirements on disturbed areas (in preparation for large scale restoration during closure phases; e.g. Site 10) and areas not suitable for use of cuttings e.g. where ground is not conducive for digging holes for planting cuttings (e.g. Type B areas). Using knowledge of dormancy breaking mechanisms gained through laboratory research, seeds will be pre-treated prior to seeding.

**Table 4 Records of *Darwinia masonii* seed collections.**

| Code | TPFL | Year | DRF Permit # | Weight (g) | Seeds / g | % viability |
|---|---|---|---|---|---|---|
| **LCS 6252** | 2 | 2008 | n/a | 372.0 | 212 | 37 |
| **LCS 6253** | 2 | 2008 | n/a | 728.0 | 210 | 45 |
| **LCS 6676** | 2 | 2010 | n/a | 570.0 | - | - |
| **MTG 12** | 2 | 2011 | n/a | 37.0 | - | - |
| **MTG 13** | 2 | 2010 | n/a | 20.0 | - | - |
| **INB** | 8 | 2015 | 28-1516 | 118.4 | 226 | 28 |
| **IND** | 8 | 2015 | 28-1516 | 60.3 | - | - |
| **INF** | 8 | 2015 | 28-1516 | 101.1 | - | - |
| **INA** | 8 | 2015 | 28-1516 | 95.8 | - | - |
| **ISB** | 1 | 2015 | 28-1516 | 46.3 | 216 | 26 |
| **ISC** | 1 | 2015 | 28-1516 | 8.2 | - | - |
| **ISD** | 1 | 2015 | 28-1516 | 9.1 | - | - |
| **EHA** | 2 | 2015 | 28-1516 | 186.0 | 222 | 29 |
| **EHB** | 2 | 2015 | 28-1516 | 51.5 | - | - |
| **EHE** | 2 | 2015 | 28-1516 | 13.4 | - | - |
| **IH18RC*** | 2 | 2015 | 28-1516 | 14.3 | - | - |

*collected from original irrigated and fenced translocation trial plants

### 3.1.4 Prospective exploration and mining areas

In order to maintain the benefits of successful translocations in the future, proposed translocation sites have been sited to avoid potential future areas targeted from mineral exploration or mine development. MGM and EHPL geologists and mine planners were consulted to determine the likelihood of the area being required for future programs that would require land disturbance; although the risk of this happening is reduced, it cannot be eliminated entirely. It is understood that any proposed disturbance to *D. masonii* plants growing on the translocation sites may require a Permit to Take.

## 3.2 Translocation areas

MGM have identified four types of prospective translocation areas:

**Type A areas** - Supplementing the original translocation trial (Trial Area #04; Augmentation)

A total of 206 plants derived from cuttings were translocated in an experimental trial in 2005 (BGPA 2010; Figure 6-A). The number of plants, within the original translocation trial near Iron Hill East, is currently 172 (Eco Logical Australia 2014). These plants had successfully reached maturity (Eco Logical Australia 2014). The current rate of survival is 83.5% since inception.

The abundance requirement for translocation was stated by Parks and Wildlife as over 200 mature plants (Draft *Darwinia masonii* Recovery Plan, August 2014). Although natural recruitment is occurring at that site, additional cuttings (approximately 50 or more plants) will be established in adjacent areas (e.g. Figure 6-B) to facilitate an increase in the size of this population. Plants would be sourced from Extension Hill stock.

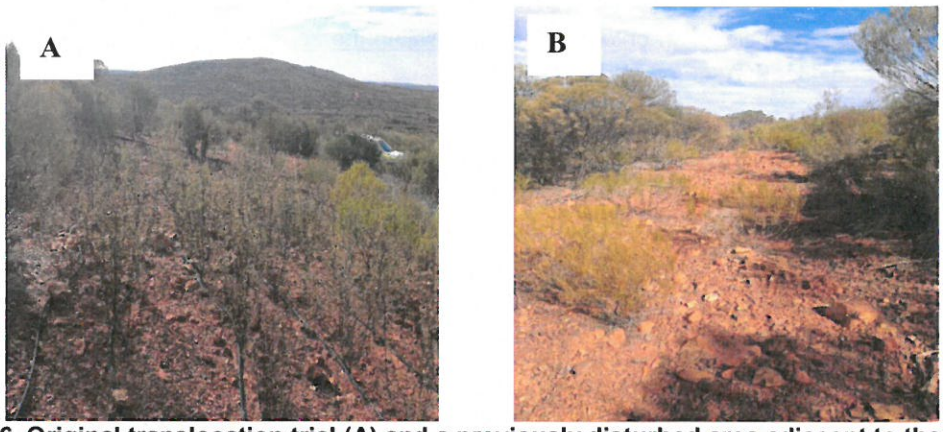


**Figure 6 Original translocation trial (A) and a previously disturbed area adjacent to the trial area (B) suitable for supplementary plantings.**

**Type B areas** - Translocation onto disturbed areas within the zone of predicted habitat (Trial areas #1, #3, #5 and #7; Reintroduction)

This trial would replicate the methodology of the original BGPA translocation trial and take into account site selection considerations (Section 4.1 above). The goal will be to establish a group of approximately 285 individuals per trial area and replicate the success of the original trial on previously disturbed areas such as available tracks (Figure 7-A) and drill pads (Figure 7-B). Site 2 may not be used for plots due to its location within an approved disturbance envelope.

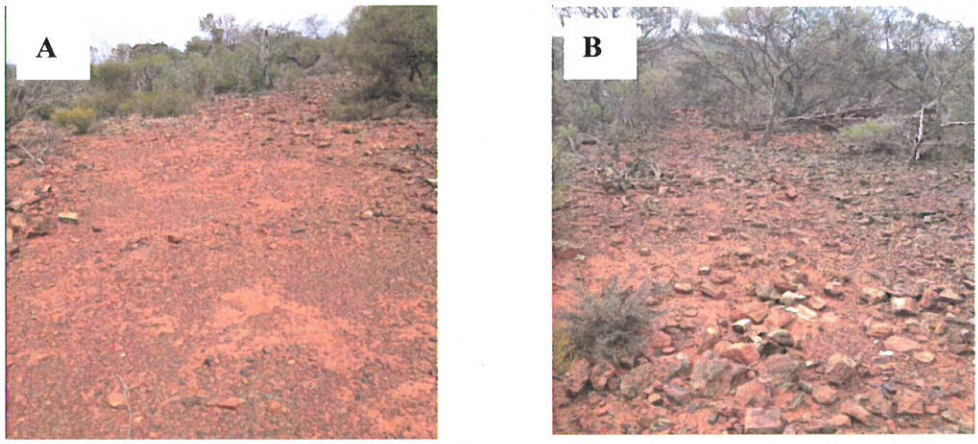


**Figure 7 Track (A) and drill pad (B) areas (Figure 3; Area 5)**

**Type C areas** - Translocation onto natural areas within the zone of predicted habitat (Trial Area #1, #2, #5 and #8, #9; Augmentation)

These trials will occur in natural areas (e.g. Figure 8-A and 8-B). A Native Vegetation Clearing Permit will be obtained prior to undertaking this part of the translocation trial. Clearing of native vegetation will be minimised by selecting areas under the canopy of native vegetation or in areas where there is a mosaic of individuals and spaces where individuals are not growing.

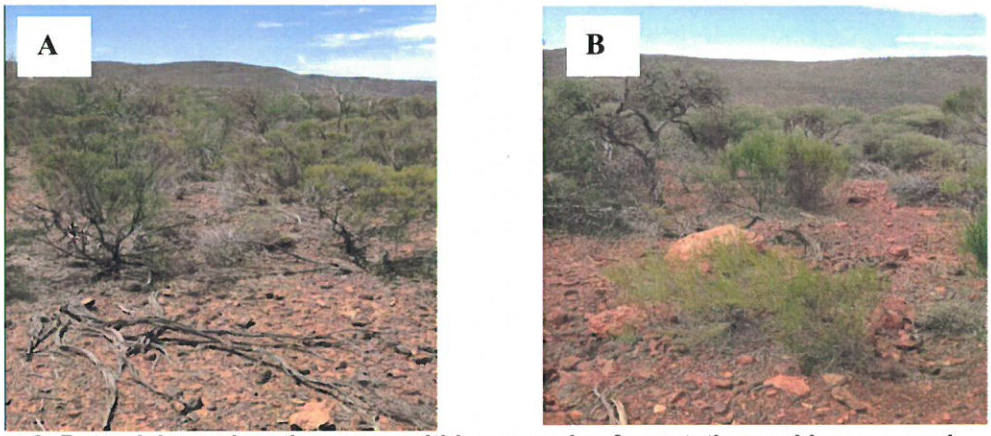


**Figure 8 Potential translocation areas within a mosaic of vegetation and bare ground (A and B; Area 5)**

**Type D areas** - Translocation onto areas outside or near zone of predicted habitat but potentially prospective for *D.masonii* (Trial Areas #6 and #7; Introduction)

These areas are currently beyond the predicted habitat (BGPA 2010) but provide the benefit of nearby certain known hilltops and slopes i.e. Area 6 south of Iron Hill South and will also provide contingency for translocations where Type A, B or C areas are not found (this may be the case for Extension Hill TPFL 2 cuttings if the Extension Hill magnetite development proceeds). These could be used as refugia sites for green stock from cut genotypes.

**Seeding trial – Site 10 Extension Hill Waste Landform (Introduction)**

This part of the trial will complement the research of Sebastian Lamoureux B.Sc (UWA PhD Candidate) by building on the outcomes of the research program, by testing the direct sowing of pre-treated, as well as, untreated *D. masonii* seed. Successfully proven dormancy breaking seed pre-treatments include burial and smoke water application (BGPA 2010). The early recommendations from the research program (and associated approved translocation program; Figure 9-A and 9-B) will inform site preparation requirements for these trials. Due to its location within an approved disturbance envelope, Site 10 may be used for trials but not for permanent plots.

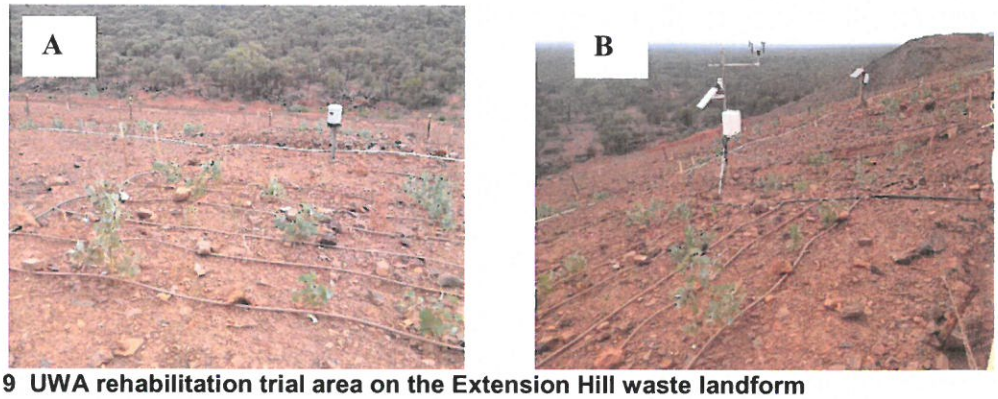


**Figure 9 UWA rehabilitation trial area on the Extension Hill waste landform**

## 3.3 Translocation timelines

It is anticipated that translocations will be established on a yearly basis for a period of two or three years as shown in Table 1. It is envisaged that approximately 1690 individual cuttings and/or seedlings will be translocated, with approximately 285 of these being planted per site at nominated sites, seeding trials involving approximately 500 seeds/trial, and supplementing the original translocation trial with 50 plants. The planting work will occur between 2016 and 2018 with monitoring occurring after irrigation has been removed.

Not all identified prospective translocation areas will necessarily be used. The program and schedule for preparing, establishing and planting nominated sites will be advised by MGM and EHPL to DPaW annually. This will also include location, substrate, elevation, slope, and source population.

The cuttings/seedlings will be derived from stock maintained by the Nuts about Natives nursery (NaNs), or from plants within the near vicinity of each selected translocation trial area.

The nominal timeline for the translocation activities is described in Table 5. Annual reporting by the proponents at the conclusion of Phase 1 (March 2017) will also make recommendations including about whether to progress to Phase 2.

**Table 5 Nominal timeline for translocation activities**

| Activity | Timeline |
|---|---|
| **2015 (Preparation year)** | |
| **Application for Scientific Permit** | Autumn 2015 |
| **Collection of Year 1 plant material (as required)** | Winter-Spring, 2015 |
| **Nursery propagation of Year 1 collected material** | Winter 2015 - Autumn 2016 |
| **Selection of two to four suitable plots in Year 1 trial areas** | Winter 2015 |
| **NVCP application submission (if required)** | Winter 2015 |
| **Seed collection from target areas** | Spring 2015 |
| **2016 (Year 1)** | |
| **Site preparation of Year 1 plots** | Autumn 2016 |
| **Selected trial plots planted with approx. 285 individuals and approx. 40-60 individuals (TPFL # 2) will be planted in the original irrigation trial (Trial area #4)** | Early winter 2016 |
| **Collection of Year 2 plant material for other trial areas** | Winter – Spring, 2016 |
| **Selection of two to four suitable plots for Year 2 trial areas** | Winter 2016 |
| **NVCP application submission (if required)** | Winter 2016 |
| **Seed burial pre-treatment for Year 2 (9-12 months)** | Winter 2016 |
| **Nursery propagation of Year 2 collected material** | Winter 2016 - Autumn 2017 |
| **Weekly monitoring of Year 1 trial plots (month 1 and 2)** | Spring 2016 |
| **Monthly monitoring of Year 1 trial plots** | Summer Dec 2016 - Feb 2017 |
| **2017-18 (Year 2 & 3)** | |
| **Site preparation of Year 2 trial plots** | Autumn 2017 |
| **Selected trial sites planted with approx. 250 individuals** | Winter 2017 |
| **Seeding trial (ST) on waste landform or other disturbed areas** | Winter 2017 |
| **Annual monitoring of Year 1 trial plots** | Spring 2017 |
| **Weekly monitoring of Year 2 trial plots (month 1 and 2)** | Winter-Spring 2017 |
| **Monthly monitoring of Year 2 trial plots** | Summer Dec,2017-Feb,2018 |
| **Monthly monitoring of Year 2 trial plots** | Summer Dec, 2018 – Feb, 2018 |
| **Annual monitoring of Year 2 trial plots** | Spring 2018 |
| **Annual monitoring of all Trial plots** | Spring 2019 - 2022 |
| **Five year monitoring of Year 1 trial plots** | Spring 2021[1] |
| **Five year monitoring of Year 2 trial plots** | Spring 2022 |

## 3.4 Plant Source and Translocation methodology

Site selection, selection of the origin of cuttings or seeds (dependent on site selection) and potential applications for a Native Vegetation Clearing Permit (NVCP) will occur over the winter periods of 2015 and 2016.

Ground preparation may be required at translocation sites. Disturbed areas may be ripped to reduce the effects of compaction that may have occurred as a result of their previous use. Translocations into natural areas will not require any site preparation other than digging holes in which to put the cuttings/seedlings.

*Darwinia masonii* cuttings will be required from *in situ* sources and are in addition to those currently held at the Nuts about Natives nursery. Cuttings and seedlings will be propagated in pots at the Nuts about Natives nursery in Karnup, Western Australia (hygiene-accredited nursery) and transported to Extension Hill mine site at the time of planting. The cuttings/seedlings will then

[1] Survival and recruitment records of *D. masonii* plants in the original translocation trial (Site #4) will have occurred over a period of almost 15 years by 2021.

be planted by hand, and placed in previously prepared holes, approximately 0.3 m in depth. A fertiliser (for Australian natives) may be added to supplement the soil in each hole.

The cuttings/seedlings will be watered in and then drip irrigation will be made available to each plant. Cuttings/seedlings will be irrigated for one hour, twice per month for the first two summers and possibly winter period (if required, due to drought or a very dry preceding or trailing winter period).

Each plant will be tagged and given a unique identifier that links it back to propagation and source information.

Where seeding is conducted, irrigation will be made available to seedlings at the end of the winter period. Seeding will be based on the following assumptions:

- Seed germination of approximately 90% (following pre-treatments; based on BGPA, 2010 research outcomes),
- Approximately 10% of seedlings may survive to the end of winter (based on BGPA, 2010 research outcomes),
- One plant/ 2 $m^2$,
- Trial area of 100$m^2$ in the first year of the trial.

On the waste landform and other disturbed areas (e.g. Type B areas), based on outcomes of the UWA translocation research program, more than one trial area with differing soil treatments may be used to determine the success of this methodology. On natural areas, the trial area will be restricted to the one area. This conservative approach builds on *D. masonii* seed research to-date (i.e. BGPA, 2010) and the outcomes of the UWA *D. masonii* translocation program.

The size of the trial area and number of resulting plants may then be supplemented in the following year to meet success criteria (defined in Section 4.6).

## 3.5 Maintenance and monitoring

The survival and condition of plants in each trial area (approx. 100 $m^2$) will initially be recorded. Cuttings/seedlings will be monitored weekly for the first eight weeks and spot irrigated if required (subject to rainfall events) to assist with early survival and plant establishment.

After two months and during the summer period, translocation sites will be visited on a monthly basis by site personnel to monitor and record plant survival for a period of two years, conduct maintenance of irrigation equipment and pumps, check water levels in water tanks and assess for herbivory (and consider using fencing if the plants are at risk of extensive herbivory).

After two years, irrigation equipment will be removed and *D. masonii* populations will be monitored on an annual basis for survival and condition for the period of five years after their translocation. Second generation plants will be recorded and tagged if evident and monitored thereafter.

After five years, monitoring will continue to measure survival, flowering and recruitment on an annual basis until such time that long-term criteria for success have been met for three consecutive years.

Seed trials will be monitored to meet the criteria for success as per the cuttings/seedlings trials (described above) and as described in the Extension Hill Closure Plan (2015).

## 3.6 Criteria for success

The aim of this translocation program will be to improve the conservation status of *D. masonii* by increasing the number of individuals on the Mt Gibson Ranges (although it should be noted that this will likely not result in a reduced legislative status under state or federal laws).

The implementation of the translocation program will be considered a success if population survival and establishment equals:

### 3.6.1 Short term criteria (approx. 2 years, with irrigation)

**Cuttings/Seedlings**

| Success Criteria | Failure Criteria |
|---|---|
| Greater than 200 individuals in each trial area (>70% survival) | Less than 200 individuals in each trial area (<70% survival) |

If monitoring outcomes reflect that the short-term success criteria have not been met, supplementary plantings of cuttings/seedlings may occur in the following year.

**Seeding Trials**

| Success Criteria | Failure Criteria |
|---|---|
| Survival of some individuals in each trial area to inform future seed density requirements. | Survival of no individuals in each trial area. |

Note that we have not specifically stated a number of individuals for seed trials because no information is currently available to determine what can be expected in comparison to the translocation of cuttings/seedlings. If no germination or survival of seedlings occur in this period then this aspect of the translocation trial may be abandoned or repeated with differing treatments.

### 3.6.2 Medium term criteria (2-5 years, without irrigation)

**Cuttings/Seedlings**

| Success Criteria | Failure Criteria |
|---|---|
| Greater than 200 individuals in each trial area (>70% survival). | Less than 200 individuals in each trial area (<70% survival) |
| Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL. | Flower production and seed set of surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL. |
| Recruitment of second generation individuals' that are equivalent to recruitment rates of individuals growing | Recruitment of second generation individuals' is less than recruitment rates of individuals growing |

| | |
|---|---|
| naturally within the nearest TPFL. | naturally within the nearest TPFL. |

Given our learnings of the effects of watering on this species for the first two years, we are expecting flower production and recruitment to occur in this medium term period. However, if there is failure then we will continue to monitor them with the expectation that flower production and recruitment will occur in the longer term.

**Seeding Trials**

| Success Criteria | Failure Criteria |
|---|---|
| Greater than 35% survival in each trial area. | Less than 35% survival in each trial area. |
| Flower production and seed set in 25% of surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL. | Flower production and seed set in 25% of surviving individuals at a lower rate compared to individuals growing naturally within the nearest TPFL. |
| Recruitment of second generation individuals' that are equivalent to recruitment rates of individuals growing naturally within the nearest TPFL. | Recruitment of second generation individuals' is less than recruitment rates of individuals growing naturally within the nearest TPFL. |

There is currently limited information of survival and establishment rates of this species when grown on a waste landform. Therefore, percentage survival and flower production is significantly lower in comparison to translocated cuttings and seedlings. We do, however, expect that if this species successfully survives and establishes on the waste landform as per other translocation trials using cuttings then it will also flower and show recruitment as a result of being irrigated in the first two years.

If there is no survival of the seedlings then this aspect of the translocation trial may be abandoned.

### 3.6.3 Long term criteria (after 5 years)

**Cuttings/Seedlings**

| Success Criteria | Failure Criteria |
|---|---|
| Survival rates are equivalent to those *D. masonii* individuals growing naturally within the nearest TPFL. | Survival rates are not equivalent to those *D. masonii* individuals growing naturally within the nearest TPFL. |
| Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL. | Flower production and seed set in surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL. |
| Recruitment of second generation individuals' that are equivalent to recruitment rates of the individuals growing naturally within the nearest TPFL. | Recruitment of second generation individuals' is less than recruitment rates of the individuals growing naturally within the nearest TPFL. |

**Seed Trials**

| Success Criteria | Failure Criteria |
|---|---|
| Survival rates are equivalent to those *D. masonii* individuals growing naturally within the nearest TPFL. | Survival rates are not equivalent to those *D. masonii* individuals growing naturally within the nearest TPFL. |
| Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL. | Flower production and seed set in surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL. |
| Recruitment of second generation individuals' that are equivalent to recruitment rates of individuals growing naturally within the nearest TPFL. | Recruitment of second generation individuals' is less than recruitment rates of individuals growing naturally within the nearest TPFL. |

If long-term criteria for success are met for three consecutive years then the plants in these trials are likely to be self-sustaining and thus concludes the requirements of this Translocation Proposal.

## 3.7 Reporting

The location, substrate, elevation, slope, and source population and then survivorship will be recorded and reported in accordance with MS753 and the *Darwinia masonii* Recovery Plan / Interim Recovery Plan reporting commitments. The presence of flowering, fruiting and seed production on the translocated plants, and presence of new recruits (including tag identification numbers and GPS readings) in the near vicinity of the trial area will also be recorded.

Medium and long term monitoring and reporting will include assessment of number of plants that are flowering, have seed set and number of recruits in natural areas within the nearest TPFL.

Annual monitoring reports and a final report at the end of the project will be provided to the Flora Administrative Officer, Species and Communities Branch, Department of Parks and Wildlife.

## 3.8 Funding

Funding of the translocation program will be the sole responsibility of MGM and EHPL.

# 4. Endorsement

This Proposal is endorsed by representatives of the proponents:

I hereby certify that to the best of my knowledge, the information within this Translocation Proposal is true and correct and addresses the requirements of *Corporate Guideline No. 36 Recovery of Threatened Species through Translocation and Captive Breeding or Propagation* (Department of Parks and Wildlife, 2015b).

*Signature* *Date*

Mr Troy Collie
Project Director, Environment and Approvals
Mount Gibson Mining Limited

*Signature* *Date*

Mr Ben McLernon
Manager, Environment & Community
Extension Hill Proprietary Limited

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# 6. Appendices

# Appendix 1 *Darwinia masonii* Draft Recovery Pan (DPaW 2015)

10-800-EN-PLA-0021

Mount Gibson Iron

Extension Hill Pty Ltd

# Mason's Darwinia
# *Darwinia masonii*

## Recovery Plan Revision 1.1
## 2015-2024

**Extension Hill Pty Ltd and Mount Gibson Mining Limited**

**November 2015**

## Abbreviations

| | |
|---|---|
| **BGPA** | Botanic Gardens and Parks Authority |
| **BIF** | Banded Ironstone Formation |
| **CALM** | Department of Conservation and Land Management, Western Australia (changed to Department of Environment and Conservation in July 2006 and Department of Parks and Wildlife in July 2013) |
| **DoE** | Commonwealth Department of the Environment (formerly DSEWPaC) |
| **DEC** | Department of Environment and Conservation, Western Australia (changed to Department of Parks and Wildlife in July 2013) |
| **DEWHA** | Commonwealth Department of Environment, Water, Heritage and the Arts (changed to DSEWPaC on 14 September 2010) |
| **DSEWPaC** | Commonwealth Department of Sustainability, Environment, Water, Population and Communities (changed to DoE on 18 September 2013, formerly DEWHA) |
| **Parks and Wildlife, DPaW** | Department of Parks and Wildlife, Western Australia (formerly CALM and DEC) |
| **EPBC Act** | Environment Protection and Biodiversity Conservation Act 1999 |
| **EHPL** | Extension Hill Pty Ltd |
| **GDTFRT** | Geraldton District Threatened Flora Recovery Team |
| **GNHwy** | Great Northern Highway |
| **IBRA** | Interim Biogeographical Regionalisation for Australia |
| **IUCN** | International Union for Conservation of Nature |
| **MGIOIP** | Mount Gibson Iron Ore Mine and Infrastructure Project |
| **MGM** | Mount Gibson Mining Limited |
| **NAN** | Nuts About Natives |
| **SCB** | Species and Communities Branch, Parks and Wildlife |
| **TPFL** | Threatened and Priority Flora Database |
| **UWA** | The University of Western Australia |
| **WA** | Western Australia |

## Foreword

Recovery plans are developed within the framework laid down in Department of Parks and Wildlife Policy Statements Nos. 44 and 50 (CALM 1992; CALM 1994), and by the Australian Government Department of the Environment (DEWHA 2008a). Recovery plans outline the recovery actions that are required to address those threatening processes most affecting the ongoing survival of threatened taxa or ecological communities, and begin the recovery process.

This Recovery Plan (plan) has been prepared to meet condition 6-3 of Ministerial Statement 753 (MS753), which authorises the implementation of the Mount Gibson Iron Ore Mine and Infrastructure Project (MGIOIP). Appendices

Appendix 10.1 demonstrates how this Plan meets condition 6-3. The Plan is consistent with the "Recovery Plan Guidelines for Nationally Listed Threatened Species and Ecological Communities under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*" (Appendix 10.2).

Information in this plan was accurate at November 2015

Cover photograph by Kiera Foster.

# Contents

**Abbreviations** ..... ii
**Foreword** ..... iii
**Summary** ..... vii
**1 Background** ..... 10
1.1 The taxon ..... 10
1.1.1 Description ..... 10
1.1.2 History, nomenclature and taxonomic relationships ..... 10
1.1.3 Biology and ecology ..... 11
1.1.4 Habitat and distribution ..... 13
1.1.5 Population history ..... 16
1.1.6 Conservation status ..... 27
1.2 Habitat critical to survival of the species and important populations ..... 27
1.3 Threatening processes ..... 29
1.3.1 Risk assessment ..... 29
1.3.2 Drying climate ..... 35
1.3.3 Mining (direct removal) ..... 35
1.3.4 Inappropriate fire regimes ..... 35
1.3.5 Mining (threatening processes) ..... 36
1.3.6 Weed invasion ..... 36
1.3.7 Grazing ..... 36
1.4 Broader biodiversity benefits ..... 37
**2 Recovery objectives and criteria** ..... 39
2.1 Plan objective ..... 39
2.2 Recovery criteria ..... 39
**3 Past and existing recovery actions** ..... 40
3.1 Coordinate recovery actions and liaise with stakeholders ..... 41
3.2 Continue implementation of the *Darwinia masonii* research programme ..... 41
3.3 Establish and implement *Darwinia masonii* condition monitoring programme ..... 42
3.4 Implement Fire Management Strategy ..... 44
3.5 Manage secondary impacts of mining ..... 44

3.6 Manage inappropriate grazing pressure on *D. masonii* ..... 45
3.7 Translocation trials ..... 45
3.8 Maintain adequate seed/germplasm collections to ensure material with a broad genetic base is available for translocation and on-going ex situ conservation ..... 48
3.9 Conduct further surveys and report any new populations of *D. masonii* ..... 50
3.10 Promote awareness of *Darwinia masonii* ..... 50
3.11 Review ranking of the species and the need for a full Recovery Plan ..... 50
**4 Future recovery actions ..... 51**
4.1 Coordinate recovery actions and liaise with stakeholders ..... 53
4.2 Develop and implement restoration strategy ..... 53
4.3 Maintain and use seed/germplasm collections as a broad genetic base for conservation ..... 55
4.4 Promote awareness of *Darwinia masonii* ..... 56
4.5 Implement *Darwinia masonii* condition monitoring program ..... 57
4.6 Implement Fire Management Strategy ..... 58
4.7 Manage threatening processes from mining ..... 59
4.8 Protect plants from herbivory ..... 59
4.9 Monitor populations ..... 60
4.10 Report any new occurrences of *Darwinia masonii* ..... 61
4.11 Review conservation status of the species ..... 61
4.12 Review this recovery plan ..... 62
**5 Further research to benefit recovery ..... 62**
**6 Legislative and decision making controls and obligations ..... 63**
6.1 International obligations ..... 63
6.2 Guide for decision makers ..... 63
**7 Interest groups, social and economic impacts and benefits ..... 65**
7.1 Role and interest of Aboriginal groups ..... 65
7.2 Affected interests ..... 65
7.3 Social and economic impacts and benefits ..... 65
**8 Implementation and evaluation ..... 66**
**9 References ..... 72**
**10 Appendices ..... 77**

# Tables

Table 1. Summary of population history and records prior to 2013 ..... 21
Table 2. Fire history of *Darwinia masonii* populations ..... 24
Table 3. *Darwinia masonii* – risk assessment based on AS/NZS ISO 31000 framework ..... 30
Table 4. Conservation–listed flora species occurring within 500m of *D.masonii* ..... 37
Table 5. Conservation–listed fauna species occurring within the range of *Darwinia masonii* ..... 37
Table 6. Past recovery actions in the *Darwinia masonii* IRP (DEC, 2008), evaluation of their implementation, and related recommendations. ..... 41
Table 7. *Darwinia masonii* seed collections held by Parks and Wildlife's Threatened Flora Seed Centre 49
Table 8. Summary of inherent, controlled and residual risks to the survival of *Darwinia masonii* ..... 52
Table 9 Summary of recovery actions over five years and indicative costs ..... 67
Table 10. Exact locations of populations of *Darwinia masonii* (not for publication) ..... 75
Table 11. Aspects of the Plan which address the matters stipulated by Condition 6-3 of MS753 ..... 77
Table 12. Aspects of the Plan which address the Recovery Plan Guidelines under the *EPBC Act* 1999. ..79
Table 13 Review Checklist ..... 89

# Figures

Figure 1. Current distribution of *Darwinia masonii* [based on data from Eco Logical (2014)] ..... 15
Figure 2. Regional areas surveyed for *Darwinia masonii* ..... 18
Figure 3 *Darwinia masonii* population structure in 2015 in relation to the fire history (1968-2010). ..... 26
Figure 4. Modelled distribution of *Darwinia masonii* habitat across the Mt Gibson Ranges (source BGPA, 2010) ..... 28

# Appendices

Appendix 10.1 How This Recovery Plan Meets The Requirements of MS753 ..... 77
Appendix 10.2 Legislative Requirements ..... 79
Appendix 10.3 Biology and Ecology of Darwinia *masonii* ..... 81
Appendix 10.4 Risk Assessment Criteria ..... 87
Appendix 10.5 Annual Review Checklist ..... 89

## 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 |
| **DPaW Region:** | Midwest | **Recovery team:** | Geraldton District Threatened Flora Recovery Team (GDTFRT) |
| **DPaW District:** | Geraldton | | |

**Current status of taxon:**

- *Environment Protection and Biodiversity Conservation Act* 1999: Vulnerable
- Specially protected under the Western Australia *Wildlife Conservation Act* 1950: Schedule 1, Extant and considered likely to become extinct or rare
- Ranked in Western Australia as Vulnerable D2 (under IUCN 2001 criteria)

**Habitat critical to survival:**

*Darwinia masonii* is ranked as VU in Western Australia and is known from Mt Gibson Ranges. Consequently, it is considered that known habitat for wild populations is critical to the survival of the species and that representations of wild populations are important. Habitat critical to the survival of *Darwinia masonii* includes:

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

**Threats:**

The main threats to the species are:

1. Mining (direct removal);
2. Drying climate;
3. Inappropriate fire regimes;
4. Mining (threatening processes);
5. Weed invasion; and
6. Grazing.

**Recovery plan objective:**

The objective of this plan is "*to maintain, and ultimately improve, the conservation status of D. masonii such that its conservation status is more secure in the Mt Gibson area*" (Ministerial Statement 753).

**Criteria for success:**

This recovery plan will be deemed successful if, over the term of the plan, all of the following are achieved:

1. The number of *in-situ* mature individuals in areas of known occupancy, outside of areas approved for disturbance under Ministerial Statements remains stable[1] or increases.

2. The conservation category of the species remains at the current status or improves.

**Criteria for failure:**

This recovery plan will be deemed unsuccessful if, over the term of the plan, any of the following occur:

1. The total number of all *in-situ* mature individuals in areas of known occupancy, outside of areas approved for disturbance under Ministerial Statements has decreased by more than 20% beyond its natural variability* as a result of effects from threats identified in section 1.3 ;

2. The conservation status meets IUCN criteria for listing at a higher threat category than the status (at the time of publication of this Recovery Plan).

* Natural variability will be assessed through regular monitoring as described in Section 4.5 and 4.9

| **Recovery actions:** |
|---|
| 1. Coordinate recovery actions and liaise with stakeholders. |
| 2. Develop and implement restoration strategy. |
| 3. Maintain and use seed/germplasm collections to ensure material with a broad genetic base is available for conservation. |
| 4. Promote awareness of *Darwinia masonii*. |
| 5. Implement *Darwinia masonii* condition monitoring program. |
| 6. Implement fire management strategy. |
| 7. Manage threatening processes of mining. |
| 8. Protect plants from herbivory. |
| 9. Report any new occurrences of *Darwinia masonii*. |
| 10. Review conservation status of the species. |
| 11. Review this recovery plan. |

[1] Stable means number of mature individuals plus or minus fifteen per cent.

**Recovery team:**

Recovery teams provide advice and assist in coordinating actions described in recovery plans. They include representatives from organisations with a direct interest in the recovery of species, including those involved in funding and those participating in actions that support the recovery of species. The co-ordination and implementation of this recovery plan will be overseen by Parks and Wildlife.

# 1 Background

## 1.1 The taxon

This section provides a summary of information pertinent to *Darwinia masonii* including its description, taxonomy, biology and ecology, habitat and distribution, population history and conservation status. More comprehensive information with respect to the taxon can be found at Appendix 10.3.

### 1.1.1 Description

*Darwinia masonii* is an erect shrub 1.5 to 3m tall, with narrow leaves approximately 1cm long, which are almost triangular in cross-section. These leaves are closely crowded towards the ends of the branchlets. The flowering inflorescences are approximately 3cm 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 2cm in length and 5mm wide at the base. Each tubular flower is about 5mm long with a style approximately 1.5cm in length with hairs below the stigma (Brown *et al*., 1998).

*Darwinia masonii* has a known flowering period from April to November (Brown *et al*., 1998). As the rainfall in the region is unreliable, *D. masonii* responds opportunistically to rainfall events (i.e. tropical cyclonic summer rainfall events and southern winter cold fronts). Strong vegetative growth (but not reproductive stages) has been observed following summer rainfall events.

### 1.1.2 History, nomenclature and taxonomic relationships

Charles Gardner (Gardner, 1964) described *D. masonii* from specimens collected by D. Mason of White Wells Station (now Charles Darwin Reserve) in about 1960.

Investigations of the phylogeny of related genera *Chamelaucium*, *Darwinia*, *Verticordia*, *Actinodium*, *Homoranthus* and *Pileanthus* have been completed to more accurately determine their taxonomic status and phylogenetic position, specifically *D. masonii*. Key results of investigations by BGPA (2005) reported:

- Genetic status of Chamelaucium and Pileanthus is confirmed (i.e. they are monophyletic).
- Eastern and Western Australia *Darwinia* species belong in separate groups.
- The genera *Chamelaucium*, *Pileanthus*, *Darwinia*, *Homoranthus* and *Actinodium* are nested within *Verticordia* as currently circumscribed.
- *Darwinia masonii* has been shown to be most closely related to three other species, *D. acerosa*, *D. purpurea* and *D.* sp. Chiddarcooping (S.D. Hopper 6944).

### 1.1.3 Biology and ecology

*Darwinia masonii* 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.

Mature plants of *D. masonii* have a slow, irregular and modular growth form (BGPA, 2010). Seedling growth forms are more regular with increases in height and stem diameter correlated with age. 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 a presence or absence of spongy bark. Individuals may be prostrate or reclining, and the canopy is not uniform in shape.

Flowering of young plants begins to occur at six years (BGPA, 2010). Flower numbers are greater for old plants with wide canopies. Flower heads form on the terminal end of branches and new vegetative shoots are produced laterally from below the terminal flowering head. Plants have been recorded flowering between April and November (Brown *et al*., 1998). In 2009, the Botanic Gardens and Parks Authority (BGPA) recorded flowers opening between late August and late October (BGPA, 2010).

*Darwinia masonii* is thought to be predominantly pollinated by birds, with a brief study recording pollination solely by the White-fronted Honeyeater (*Phylidonyris albifrons*) (BGPA, 2010). *Darwinia masonii* is capable of producing low-viability, self-pollinated (selfed) seed. There was weak evidence that selfed seed were less fit than outcrossed seed (BGPA, 2010). However, due to the low viability of selfed seed, the production of outcrossed seed would be important for self-sustaining populations (BGPA, 2010).

*Darwinia masonii* seed production is moderately low, with between 15% and 30% of developed fruits in an infructescence containing filled seed (BGPA, 2010). The mean number of filled seeds per infructescence in BGPA's study (2010) was 2 to 4.5 and, on average, between 25 and 75 filled seeds were produced per flowering plant. Seed production takes place in spring and early summer with the peak of ripe seed production in the 2009 season occurring around mid-November (BGPA, 2010). The peak period for seed collection depends on the relative rates of seed development and seed drop and may vary between years and localities. Seed dispersal occurs by ants. Predation by moth larvae, and self-pollination resulting in inbreeding, contribute to reduced seed quality and quantity.

Large scale production of seedlings of *D. masonii* via germination of fresh or stored seed involves physical manipulation of small seeds for seed coat nicking or removal, or retrieval of seed buried for months or years (BGPA, 2010). Seed of *D. masonii* has physical and physiological dormancy process (removal/breakdown of fruit walls and stimulatory effect of smoke chemicals, respectively). 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. Germination rates of 90% were achieved with filled seed exhumed after 9 months (in September 2009) of burial and treated with smoke water. The trial ran for a period of 15 months (until March 2010), however seeds have been recovered as recently as May, 2014 and provided to BGPA. There are buried seed caches *in-situ* on the south western slope of Mt Gibson.

There is also evidence of limited inter-fire recruitment of *D. masonii*. Fire history mapping has been used to explain the demography of the *D. masonii* population (see Section 1.1.5).

*Darwinia masonii* plants are long-lived and can be killed by fire (Armstrong and Associates, 2004; BGPA, 2010 Section 1.1.5). Plants arising from seed germinate in a single cohort post-fire. A wildfire burnt out a significant area in southern and eastern portions of the Ranges in January 2003. None of the *D. masonii* plants burnt during this fire survived during the spring of 2003 (Armstrong and Associates 2004).

In the absence of fire, there is evidence of limited recruitment of *D. masonii* in older populations (BGPA, 2010). Plant sizes from data collected in 2007 during BGPA's demographic study ranged in height up to 240cm and 2.5m in canopy width. The largest stem diameter was 74mm. Plant size correlated with population age in frequency distribution graphs of the young (last burnt in 2003) and mature (last burnt in 1969) plots which showed distinct peaks in size and a narrow size range. The older (last burnt before 1968) plots were estimated to have been unburnt for over 85 years and had the oldest and largest plants in them. However, the frequency distribution graphs did not have distinct peaks in size, but rather a spread of plant sizes. The data from the older plots confirmed that *D. masonii* is long-lived and that some recruitment (although very limited in the number of recruits) occurs at infrequent intervals in the absence of fire.

Regeneration after fire is restricted exclusively to germination from seed held in long-lived soil-stored seedbanks (BGPA, 2010). Recruitment in plots within the boundary of an experimental fire conducted by BGPA in May 2009 confirmed that *D. masonii* germinates strongly after fire, with a seedling density in burnt areas of 1.2/$m^2$ and 3.2 seedlings per pre-fire adult (BGPA, 2010). A fire, which occurred on the 12$^{th}$ of May, 2009 was not as intense as anticipated and was patchy, such that 73 of the 93 pre-fire adults were burnt. However, it achieved what was intended: The fire killed the plants' canopy; there was a good amount of ash produced; and, seedlings emerged. Soil temperature at some of the probe sites did reach 250°C (B Miller 2013, pers. comm., 17 December). 233 seedlings were counted in 2009 (BGPA, 2010) and 41 seedlings were counted in 2013 (J. Sackmann 2014, pers comm 30, November) within the area burnt of the four experimental fire plots, in comparison to recruitment of only one seedling in the 15 unburnt plots over the course of the study (May 2007 to June 2010). This seedling was recorded in an older (pre-1968) plot on Mt Gibson South in July 2009. This corroborates with the findings of BGPA's population structure study - recruitment occurs in older populations, but is very limited in the absence of fire.

BGPA (2010) reported that, "*While mortality is rare among mature* Darwinia masonii *plants, drought over the winter of 2010 contributed to a significant level of mortality (>10% in one site)*" (p6).

There is significant spatial and temporal variation in mortality of *D. masonii* seedlings (BGPA, 2010). The death rate for seedlings monitored between 2007 and 2009 in five plots last burnt in 2003 ranged from 2.5% to 15% per year. Possible reasons for the variation in seedling mortality included seasonal variation in rainfall, soil water holding capacity and the microclimate of each plot. BGPA suggested that low survival rates of *D. masonii* seedlings (9% survival within one year of being tagged as having germinated over the winter period) in plots following an experimental burn may partly have been attributed to the drought over the following winter.

*Darwinia masonii* shares with co-occurring species, the drought avoiding strategy of closing down transpiration and photosynthetic function to enter a period of physiological dormancy through drought, with the capacity to restore tissues as soils wet (BGPA, 2010).

Roots of *D. masonii* have a capacity to enter large cracks, pores and fissures in regolith and may achieve considerable root depths (BGPA, 2010). *Darwinia masonii* also has a clear association with Vesicular-Arbuscular Mycorrhizae (VAM) (BGPA, 2010). These attributes assist the species to persist in environments with low water and nutrient availability.

The *Darwinia masonii* Interim Recovery Plan (IRP) (DEC, 2008) stated that "only very minor grazing pressure from feral goats and rabbits of *D. masonii* has been observed to date" (p10) and BGPA (2010) found that grazing by vertebrates (presumed to be goats and rabbits) had no impact on *D. masonii*. BGPA (2010) conducted monitoring of 378 seedlings and adult plants between 2007 and 2010 in demography plots, and a further 277 seedlings in plots established in an area subjected to the experimental burn. No evidence of mammalian herbivory was observed on any plant (seedling or adult) monitored. Branch tip pruning of 4 tagged plants was observed in 2007 and was presumed to have been caused by parrots eating flowers or seeds. No evidence of herbivory on *D. masonii* has been recorded during monitoring which has been conducted annually since 2010 by MGM. Twenty two quadrat monitoring sites within 6 populations of *D. masonii* are monitored (refer to Table 1). BGPA (2010) thus concluded that grazing by vertebrates (presumed to be goats and rabbits) had a negligible impact on *D. masonii*.

Termites did not appear to be significant on the mean growth rates and health scores of *D. masonii* (BGPA, 2010).

Foliar loss or damage by insect attack was only noted in the form of galls on a very small number of *D. masonii* individuals (BGPA, 2010). Insect attack is thus not considered to be a significant threat to the species.

Modelling of species distributions against spatially mapped environmental data found that the principal environmental parameters predicting the distribution of *D. masonii* were slopes over 7-8º, elevation over 380m AHD and all geology types within the Mt Gibson Ranges except "White Rock (unclassified, including granite and its group, acidic dyke rocks, feldspar porphyry and meta-sediments phyllitic rock)" (BGPA, 2010). However, many areas in the Mt Gibson Ranges where populations were predicted to occur by the modelling do not necessarily support extensive records of adult *D. masonii* plants. This may, in part, be due to the historical *D. masonii* survey methodology. Recent surveys have made records in some of the areas (Maia 2014; Eco Logical Australia 2014) predicted by the models as being suitable habitat for the species. 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 longer-term (prior to the 1960s) fire history patterns, and this may also account for the absence of *D. masonii* plants in areas predicted as having suitable habitat.

### 1.1.4 Habitat and distribution

*Darwinia masonii* is found within the Mt Gibson Ranges, 350km north-east of Perth. *Darwinia masonii* is predominantly restricted in its distribution to the upper slopes, crests and ridges of the eleven major hills that comprise the 6km range. The current distribution of *D. masonii* is mapped in Figure 1.

Research (Muir, 1995, Bennett, 2000, Paul Armstrong and Associates, 2004 and ATA Environmental, 2005) suggests that D. masonii is restricted in distribution to the Mt Gibson Ranges. Areas with similar geology (banded ironstone formation or chert) and vegetation to that at the Mt Gibson Ranges were surveyed by Paul Armstrong & Associates (2004), ATA Environmental (2004), BGPA (2008) and Maia Environmental Consultancy (2014a, 2014b), however no additional records have been located to date during these surveys in places other

than Mt Gibson Ranges (Figure 2). There is anecdotal evidence (Muir, 1995) that *D. masonii* may have been previously recorded from Mt Singleton, although brief later examinations of the site by Paul Armstrong and Associates (2004) and ATA Environmental (2004) did not identify the species at this location.

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 was not provided for the specimen, but it was databased in 1990, so was collected prior to 1990 (K Knight 2014, pers. comm.). The location of this specimen is provided in the WA Herbarium database as being between 1 and 2km north-west of Mt Gibson Homestead within the Mt Singleton Range. Due to the lack of detailed location description and no supporting maps or sketches, this location is unreliable, and actual location on Mt Gibson Station where the specimen was collected is unknown. Searches have been conducted on the Mt Singleton Range, as described in Section 1.1.4, and no occurrences of *D. masonii* have been recorded to date.

All other specimens of *D. masonii* held by the WA Herbarium were collected from the Mt Gibson Ranges.

The habitat where *Darwinia masonii* grows was described by Brown *et al*. (1998) as tall shrublands on yellow-brown clay loams on the Banded Ironstone Formations. ATA Environmental (2004) targeted survey recorded *Darwinia 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.

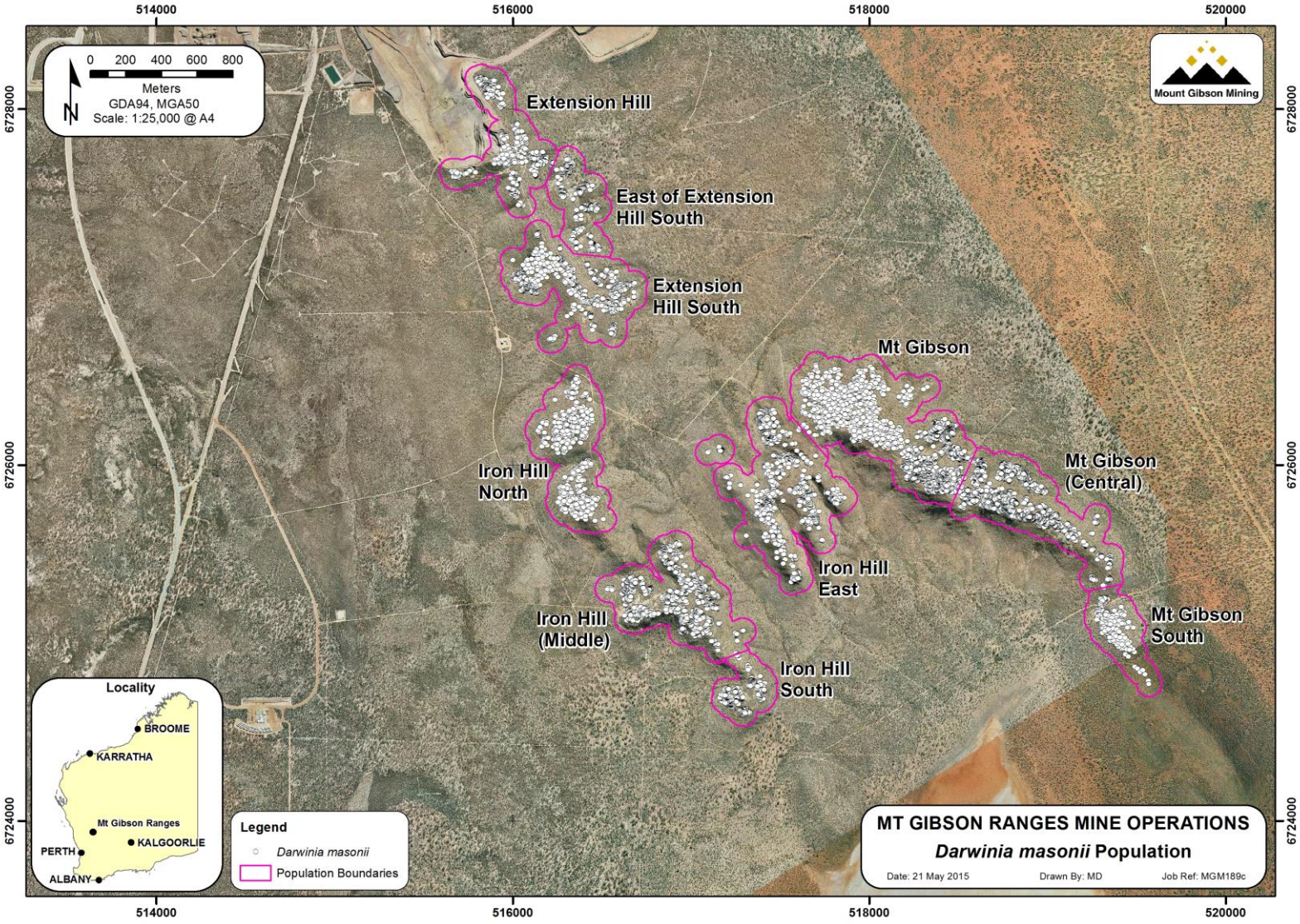



**Figure 1. Current distribution of *Darwinia masonii* [based on data from Eco Logical (2014)]**

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, and four of these were restricted to the Mt Gibson Range. *Darwinia masonii* was only present in two of the communities restricted to the Mt Gibson Ranges, 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 *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*.

### 1.1.5 Population history

Parks and Wildlife have collated the data from numerous surveys into the Threatened and Priority Flora database (TPFL) and identified 10 populations of *D. masonii*, all of which occur on the Mt Gibson Ranges (Table 1).

Previous surveys of *D. masonii* within the Mt Gibson Range were undertaken by Muir Environmental (1995), Bennett Consulting (2000), Paul Armstrong & Associates (2004) and ATA Environmental (2004). Bennett Environmental Consulting (2000) reported on nine populations. Muir Environmental (1995) recorded 10 populations, while Paul Armstrong and Associates (2004) recorded seven populations.

Maia (2014a) reported on their *D. masonii* targeted survey in December 2013 at Mt Gibson South (TPFL 7). Each plant within the area surveyed (which covered the entire population) was recorded, along with its location, height, age, reproductive status and health. Their survey also included two other study areas, one on a hill south of Iron Hill South, and the other to the north-west of Mt Gibson Homestead (Figure 2). The location of

the latter corresponded to the specimen held in the WA Herbarium of *D. masonii* from the locality of Mt Gibson Station (PERTH 01105450). Commentary relating to the accuracy of the location of this specimen has been provided in Section 1.1.4. Maia (2014a) searched an area of 25.1 ha for this record and did not find evidence of *D. masonii* within the area searched. *D. masonii* was not found in either of these study areas on the hill south of Iron Hill South.

Maia (2014b) was also engaged to conduct a targeted regional survey for *D. masonii* in June 2014. Nine areas were surveyed, as shown in Figure 2. No *D. masonii* plants were located in any of the nine areas.

The most recent and comprehensive survey for *D. masonii* was conducted by Eco Logical (2015) across all ten populations in 2014 (four trips between May and October 2014).

**Figure 2. Regional areas surveyed for *Darwinia masonii***

**Population size**

In 2004, a census of the *D. masonii* population recorded 16,573 individuals, comprising 14,307 mature individuals (86%), 1,725 seedlings (10%) and 541 senescent (dead) individuals (3%) (ATA 2004). That census formed the basis for the original environmental assessment for the approved mine operations at the Mt Gibson Ranges (ATA 2006a; EPA 2006a; WA Minister for Environment 2007), for which approximately 15% of the total *D. masonii* population were approved for removal; equating to approximately 17% of the mature *D. masonii* population.

Since the initial ATA (2004) census, additional surveys by Coffey (2008a), MBS (2013) and Maia (2014) have improved the knowledge on the *D. masonii* population at the Mt Gibson Ranges, with the population records subsequently increased prior to 2014 to 17,818 *D. masonii* individuals (DPAW 2014d).

Based on ATA (2004) and Coffey (2008a), a total of 1,702 *D. masonii* records coincided with the development of the approved mine operations to date (MGM & EHPL 2014a).

A census for *D. masonii* individuals was undertaken during 2014 to provide a contemporary record of the abundance and distribution of the *D. masonii* population at Mt Gibson Ranges. The census recorded 20,965 extant *D. masonii* individuals, comprising 19,132 mature individuals (91%), 1,580 juveniles (8%), 188 seedlings (less than 1%) and 65 senescent individuals (less than 1%) (Eco Logical 2015a).

Based on the Eco Logical (2015a) *D. masonii* census population data of 20,965 individuals, together with the 1,702 individuals removed to date by the as part of the existing approved Extension Hill mine development (MGM & EHPL 2014a), the total pre-disturbance *D. masonii* population is estimated at 22,667 individuals. This revised *D. masonii* population of 22,667 individuals is more than 6,000 individuals greater than the 16,573 individuals originally reported ten years before by ATA (2004); these 2014 data were used in the environmental assessment of the existing approved Extension Hill mine operations.

The notable increase in the total population records for *D. masonii* between the ATA (2004) and Eco Logical (2015a) census records is considered largely a result of the greater survey extent undertaken by Eco Logical (2015a), rather than an increase (greater than 30%) in the population over time (noting there were no environmental factors (e.g. fire) between the census periods which could have resulted in such an increase).

Key features are, since the IRP was published in 2008 (DEC, 2008) are:

- Approximately 1,702 whole plants have been taken from TPFL populations 2 and 3 for the approved MGIOIP hematite mine (under Permit to take number 70b-0809). This comprises all of TPFL population 3 and part of TPFL population 2.
- TPFL population 10, which was not listed in the IRP (2008), was partially surveyed in 2013 and 43 mature plants were recorded. Many additional records now exist as a result of the Eco Logical census (2015);
- TPFL population 7 on Mt Gibson South was surveyed in detail in December 2013, and the number of mature plants recorded was 837, which is 513 plants more that when it was surveyed in 2004 (Maia, 2014a). Further records were also made in that area by Eco Logical (2015);

- Many additional records exist in TPFL population 5A, 5B on Iron Hill East;
- The highest density and occurrence of records occurs on the northern part of Mount Gibson;
- There are only a small number of records (being 16) that are not situated in one of the ten TPFL numbers;
- A historical record of *D. masonii* in NatureMap lies on Mt Gibson Station towards Mt Singleton, although no detailed survey record exists. Maia (2014a) searched an area of 25.1 ha for this record and did not find evidence of D. masonii within the area searched.

The revised population of the 2014 census (Eco Logical 2015) indicates that there were more than 6,000 extra records when compared to ATA (2004).

Since the records made prior to 2013, which gave the sense of discrete groups on and around ridgetops, there is a blending of records through certain TPFL Population Numbers being:

- The southern part of Extension Hill and the northern part of Extension Hill South;
- The eastern part of Iron Hill East with the western part of Mount Gibson; and
- The southern part of Mt Gibson with the northern part of Mt Gibson South.

Well placed but arbitrary separators were made in order to 'assign' a plant record to the existing TPFL Population number in Table 1. These separators are shown in Figure 1.

**Table 1. Summary of population history and records prior to 2013**

| TPFL Pop No. | IRP Pop No. | Date of first database record (database) | Broad location description | Take status | WA Herbarium Sheet (PERTH No.) | Quadrat monitoring site | Date of most accurate monitoring record (method) | Number of plants (IRP) Pre-2014 | Number of plants Eco Logical (2014) | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 01/01/1994 (TPFL) | Iron Hill South | Extant | 06874460 | D4, D5, D6, D7, D8, D24 | 19/07/2004 (estimate) 11-17/06/2014 (actual) | 1,601 (970) [133] | 494 | Majority of area was burnt in Jan 2003 wildfire.<br><br>Last census in 2014. |
| 2 | 2 | 11/05/1995 (TPFL) | Extension Hill | Partially taken - hematite pit | 07356595 | D1 | 19/07/2004 (estimate) 11-17/06/2014 (actual) | 1,924 (12) [25] | 1,876 | Last census in 2014. |
| 3 | 1 | 11/05/1995 (TPFL) | Extension Hill North | Taken | 05313368; 06874495 | | 19/07/2004 (estimate) Present | 545 (12) [12]<br><br>0 (0) [0] | 0 | TPFL 3 has been taken. |
| 4 | 3 | 01/10/2003 (TPFL) | Extension Hill South | Extant | | D2, D3, D16, D17, D18 | 19/07/2004 (estimate) 11-17/06/2014 (actual) | 1,874 (26) [32] | 2,082 | Last census in 2014. |
| 5A, 5B | 7 | 10/1950 (WA Herb) | Iron Hill East | Extant | 01005820; 01005382; 01005790; 01005367; 01005812; 01005359; 01005804; 01005855; 01005375; 01005839; 01005340; 01005847; 00137626; 00719536; 02521741; 02521733; 06796680; 01000691 | | 19/07/2004 (estimate) 11-17/06/2014 (actual) | 70 (11) [8] | 1,692 | Did not survey areas (majority) burnt by Jan 2003 wildfire during census in 2004.<br><br>Last census in 2014. |
| 6A, 6B, 6C | 8 | 28/07/1986 (WA Herb) | Mt Gibson | Extant | 07290810 04977025 (no det) | D9, D10, D11, D12, D21, D22, D23 | 19/07/2004 (estimate)<br><br>11-17/06/2014 (actual) | 7,021 (61) [278] | 9743 | July 2004 survey area did not include area burnt in Jan 2003 wildfire.<br><br>Census in 2014 over Mt Gibson (6,226) and Mt Gibson (central) (3,517). |

| TPFL Pop No. | IRP Pop No. | Date of first database record (database) | Broad location description | Take status | WA Herbarium Sheet (PERTH No.) | Quadrat monitoring site | Date of most accurate monitoring record (method) | Number of plants (IRP) Pre-2014 | Number of plants Eco Logical (2014) | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 9 | 01/01/1994 (TPFL) | Mt Gibson South | Extant | | D13, D14, D15 | 19/07/2004 (estimate)<br>11-17/06/2014 (actual) | 324 (1) | 883 | Eco Logical (2014) recorded additional specimens further south from those of Maia (2014). |
| 8 | 5 | 11/05/1995 (TPFL) | Iron Hill Middle | Extant | 06874509 | | 19/07/2004 (estimate)<br>11-17/06/2014 (actual) | 370 (597) [18] | 1,657 | Majority of area was burnt in Jan 2003 wildfire.<br>Last census in 2014. |
| 9 | 4 | 11/05/1995 (TPFL) | Iron Hill North | Extant | | D19 | 19/07/2004 (estimate)<br>11-17/06/2014 (actual) | 586 (33) [34] | 1,951 | Majority of area was burnt in Jan 2003 wildfire.<br>Last census in 2004. |
| 10 | Not listed | 12/2/2008 (TPFL) | E of Extension Hill South (~450m SE of TPFL pop 2) | Not taken | | | 24/09/2013 (Partial survey, low quality)<br>12/02/2008 (estimate)<br>11-17/06/2014 (actual) | 43 (0) [0]<br>Several hundred | 587 | Partial survey, low quality in 2013.<br>Last census in 2014. |

* This population has been partially taken. Approximately 1,702 plants have been removed for the hematite mine, which infers that the number of plants remaining may be 767.

() = number of seedlings/juveniles; [] = number of dead

Plants related to past planting trials are not recorded in the above table. These may account for in the order of 200 plants.

**Population genetics**

Genetic research of *D. masonii* found low genetic differentiation demonstrating weak population structure between seven *D. masonii* groups (BGPA, 2010). Analysis of Molecular Variance (AMOVA) partitioned 94% of the variation within the groups, and 6% between groups. However, pairwise permutation tests between each of the tested groups showed that there is a distinction (a departure from completely random mating) between some of the groups. Two groups (TPFL no. 4 and 7) were statistically different from each other and all remaining sampled groups. Based on BGPA (2010), they were therefore interpreted as being genetically isolated from each other and all other tested groups. These TPFL's are located on Extension Hill South and Mount Gibson South. Various theories were put forward as potential reasons for this distinction between groups including: groups being disjunct; age of the population since fire causing the DNA analysis from that population 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. However, it should be noted that *Lepidosperma gibsonii* shows groups in those same locations (i.e. Extension Hill South and Mount Gibson South) being disjunct from each other. The alignment between the two species is the strongest evidence that this is not a genetic difference, but an external influence e.g. possibly soil type, soil water relations etc. that causes a difference in flowering time between sites (G. Dale 2015, pers. comm., 10 March, 2015).

Aside from these two groups, other groups showed no difference and are described as being a "*single, panmictic, interbreeding population*" (BGPA, 2010).

Results from a recent assessment of *D. masonii*, however, confirm a weak genetic structure in the nuclear microsatellite data, with nearly all populations exhibiting isolation-by-distance (M Barrett 2013, pers. comm.). The further any two populations are from each other, the more different they are on average. Nearly all populations show unique chloroplast haplotypes, suggesting that seed dispersal is very limited, and has been for a considerable time. These recent findings imply that the genetic diversity of *D. masonii* is partly described by the populations of this taxon, and the inference is that loss of population diversity may have implications for the genetic diversity of the species.

**Factors affecting population history**

Fire

Fire history mapping indicates four major fires have occurred since 1969 over the extent of occurrence of *D. masonii* (BGPA, 2010). These have been dated at 1969, 1972, 7 to 10 February 2003 and December 2005. The dating of the first two recorded fires may be imprecise and vary by a year or two, but is considered insignificant relative to the long time since these fires. No information is available regarding the intensity of the fires, completeness of the fires or the timing of the fires dated 1969 or 1972.

*Darwinia masonii* is fire-killed (see Section 1.1.3), so the fire history of the populations can be used to determine the population age. The time since fire of the populations of *D. masonii* varies from four years (juvenile status) to greater than 50 years (old status) (Table 2). Population 7 on South Mt Gibson South is old and has not been burnt for over 50 years, while the majority of populations 2, 10 and 4 on Extension Hill South are mature and were last burnt in 1969. A small experimental fire was conducted in population 2 in 2009, but the remainder of the population has not been burnt since 1969. The western part of population 9 on Iron Hill North is mature,

having not been burnt since 1972, while the eastern part of population 6 (a, b and c) on Mt Gibson Hill has not been burnt since 1969 and is also mature.

Part or all of six populations (1; 3; 5A and B; 6A, B and C; 8; and 9) are young, having been last burnt in 2003 or 2005 (Table 2). Of the six young populations, only population 1 on Iron Hill South has been burnt once within the last 50 years (in 2003). The other five populations (3; 5A and B; 6A, B and C, 8; and 9) have been burnt twice. Within population 8 on Iron Hill Middle and 9 on Iron Hill North, the boundaries of the fires in 1972 and 2003 did not overlap to a large degree, so only a small proportion of this population has been burnt twice. A majority of population 3 on Extension Hill North was burnt in both of the fires in 1969 and 2005. This population has been taken during mining activities. A majority of populations 5A and 5B on Iron Hill East have been burnt in fires in 1969, and again about 10 years ago, in 2003. The western side and part of the top of Mt Gibson Hill (populations 6A, B and C) was burnt in these same fires.

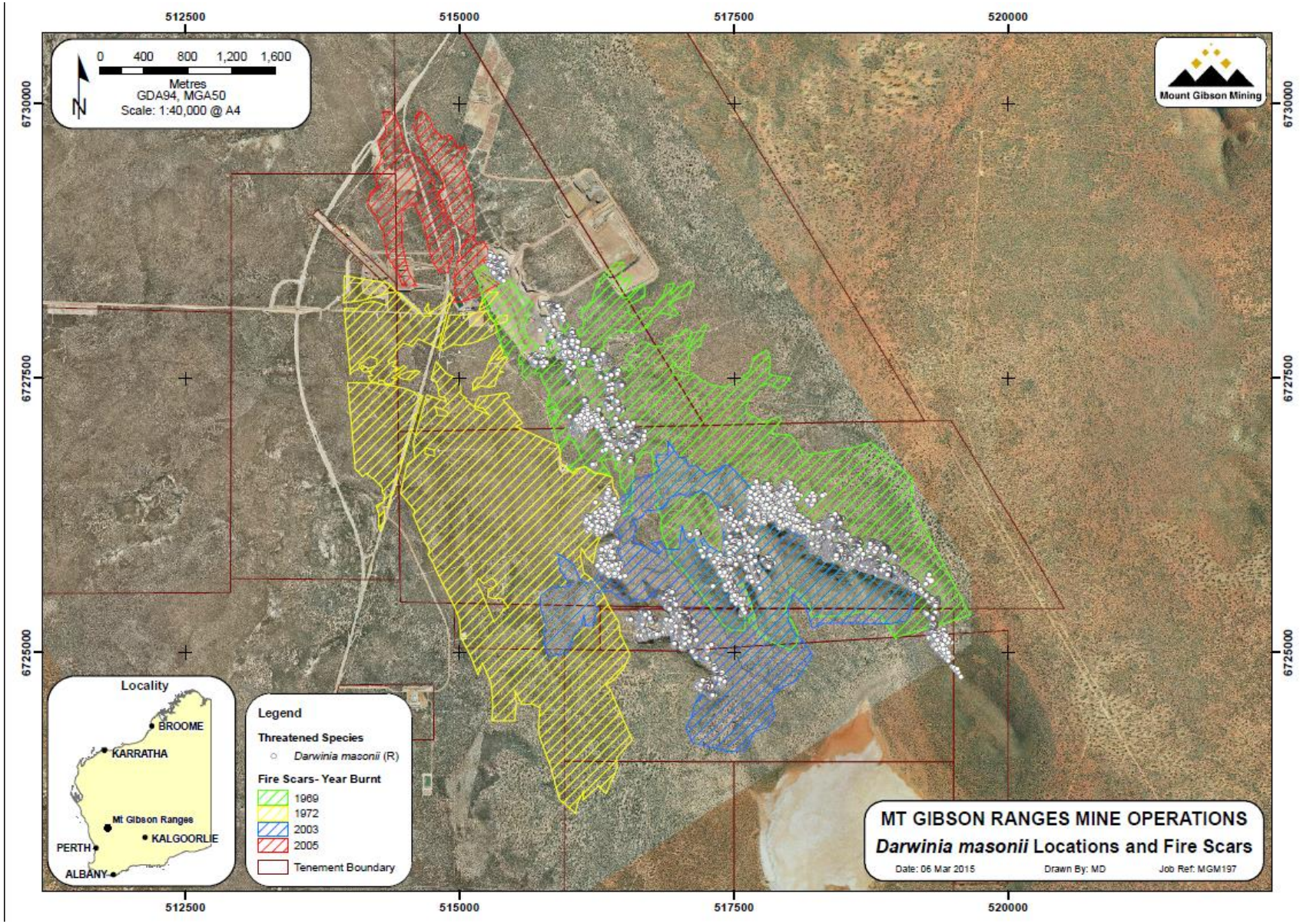
Additional individuals have been found in the southern areas of Mt Gibson south and appear to be an extension of TPFL population # 7. A fire event has not been recorded in this area.

**Table 2. Fire history of *Darwinia masonii* populations**

| TPFL Population | Fire year/s | Time since fire (years) | Fire history status | Fire impacts |
|---|---|---|---|---|
| 1 | 2003 (7-10 Feb)<br>Pre-1968 | 12<br>>47 | Young<br>Old | Majority of population within fire boundary |
| 2 | 2009 (12 May)<br><br><br><br>1969<br>Pre-1968 | 6<br><br><br><br>46<br>>47 | Juvenile<br><br><br><br>Mature<br>Old | <2ha (small) experimental fire at track junction – patchy, but achieved intended result (killed canopy, ash produced, seedlings emerged).<br><br>Majority of population within fire boundary |
| 3 | 2005 (Dec)<br>1969<br>Pre-1968 | 10<br>46<br>>47 | Young<br>Mature<br>Old | Majority of population within fire boundary<br>Majority of population within fire boundary |
| 4 | 1969 | 46 | Mature | Entire population burnt |
| 5A, B | 2003 (7-10 Feb)<br>1969 | ~12<br>46 | Young<br>Mature | Entire population burnt<br>Majority of population within fire boundary |
| 6A, B, C | 2003 (7-10 Feb)<br><br>1969 | ~12<br><br>46 | Young<br><br>Mature | Fire boundary includes west side of Mt Gibson and top of part of the hill only<br>Entire population burnt |
| 7 | Pre-1968 | >47 | Old | |
| 8 | 2003 (7-10 Feb)<br>Pre-1968 | ~12<br>>47 | Young<br>Old | Not all burnt |
| 9 | 2003 (7-10 Feb)<br>1972<br><br>Pre-1968 | ~12<br>43<br><br>>47 | Young<br>Mature<br><br>Old | Not all burnt<br>Fire boundary includes west side of Iron Hill North only |

| TPFL Population | Fire year/s | Time since fire (years) | Fire history status | Fire impacts |
|---|---|---|---|---|
| 10 | 1969<br>Pre-1968 | 46<br>>47 | Mature<br>Old | Population boundary unknown |

**Figure 3 *Darwinia masonii* population structure in 2015 in relation to the fire history (1968-2010).**



Mining and Infrastructure Development

MGM and EHPL have Ministerial approval and a permit to take approximately 2,100 adult plants which is inclusive of all vegetation within the approved footprint (Ministerial Statement (MS) No 753). Proportionally, this equated to 15% of the total number of plants known as at June 2008. A total of 1,702 mature individuals have been removed to date – corresponding to all of TPFL 3 and part of TPFL 2 (Table 1). Plants in the immediate vicinity of mining activities may be at greater risk of potential threatening processes of mining. Mining of the approved footprint (MS 753) began in 2010. A plant health monitoring program has occurred on a monthly basis since this time. To date, there have been no detectable effects as a result of threatening processes on this species from mining (Astron Environmental, 2014).

Planting trials

Plants grown from clones of the genotypes sourced from the group known as TPFL 3 and established in two planting trials undertaken by BGPA (2010):

1. A trial investigating the effects of irrigation and herbivores was established in May 2005 in a fenced plot at Iron Hill East. This was re-visited in March 2014 and 168 plants (81% of the original 206 plants) within the fenced plot were still alive, despite having not been watered for 7 years (J. Sackmann 2014, pers comm., 6 May).
2. A trial investigating establishment on different soil substrates was established in the winter of 2009 north of the hematite mine. By April 2010, the only *D. masonii* plants, which had survived were in BIF rock and BIF gravel sites. None had persisted in sand or clay sites. In 2015, there are plants present at the BIF rock and BIF gravel trial sites, although this trial has not been re-visited since the technical research was reported in 2010.

### 1.1.6 Conservation status

*Darwinia masonii* is specially protected under the Western Australian *Wildlife Conservation Act 1950* and is ranked as Vulnerable (VU) in Western Australia under the International Union for Conservation of Nature (IUCN) 2001 Red List criterion D2, due to a very restricted area of occupancy (typically less than 20km$^2$) with plausible future threats that could drive the taxon to Critically Endangered or Extinct in a very short time. Furthermore, *D. masonii* was listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in July 2000.

## 1.2 Habitat critical to survival of the species and important populations

*Darwinia masonii* is ranked as VU in Western Australia and is known from the Mt Gibson Ranges. Consequently, it is considered that known habitat for wild populations is critical to the survival of the species and that representations of wild populations are important. Habitat critical to the survival of *Darwinia masonii* includes:

- the area of occupancy of populations,
- areas of similar habitat surrounding and linking populations (these providing potential habitat for population expansion and for pollinators),

- additional occurrences of similar habitat that may contain undiscovered populations or a dormant seed bank of the species or be suitable for future translocations, and
- 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 critical to survival of the species (Figure 4). This mapping should be considered in the context of the research findings:

- The modelling predicted *D. masonii* to potentially occur broadly across the Mt Gibson Ranges with a high probability (60-75 %) of occurrence (BGPA, 2010; Section 1.1.3). However, there were many areas in the Mt Gibson Ranges where *D. masonii* plants were most highly predicted to occur by the modelling, but do not support *D. masonii*. This has since, in part, been rectified with recent surveys (Eco Logical Australia 2014, Maia 2014) finding plants in some locations of predicted suitable habitat. BGPA (2010) also speculated that the distribution of *D. masonii* may have an association with unmapped sub-surface features such as regolith (soil depth, underlying rock structure) and longer-term fire history patterns. This information may further inform the habitat requirements of this species.

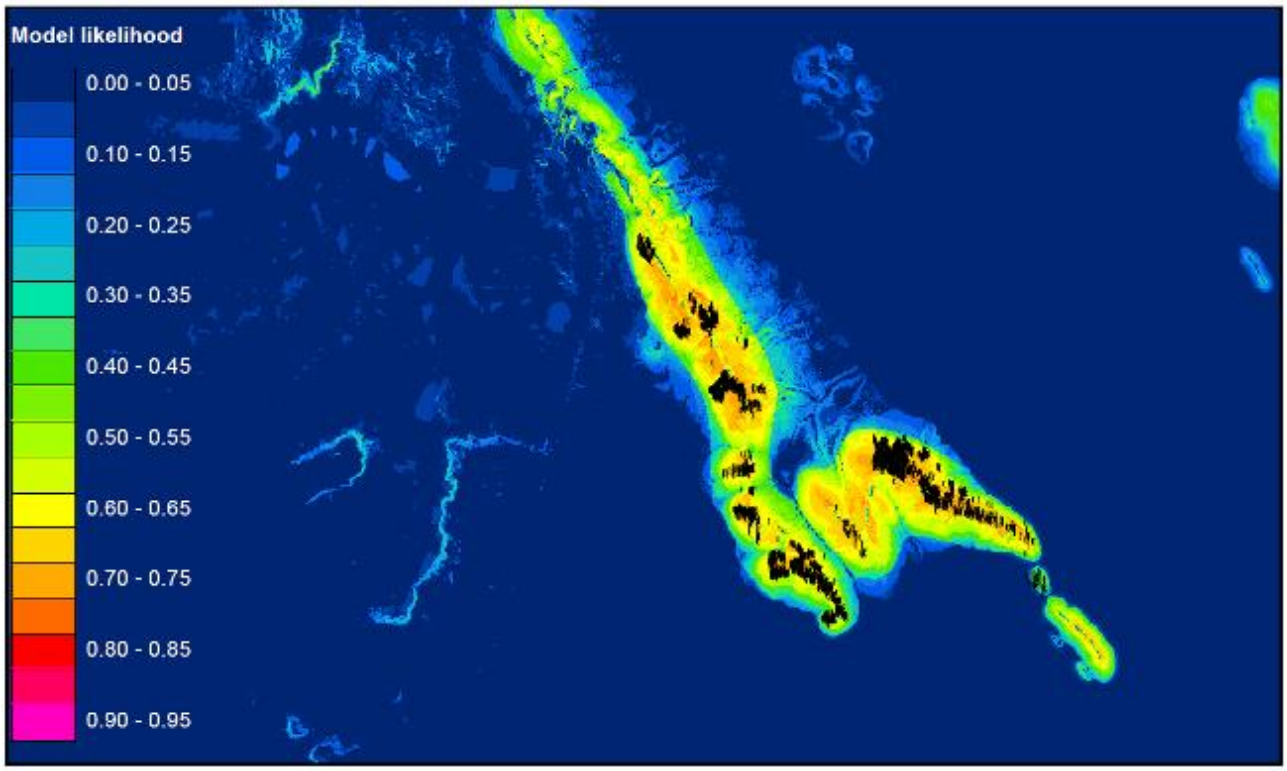



**Figure 4. Modelled distribution of *Darwinia masonii* habitat across the Mt Gibson Ranges (source BGPA, 2010)**

## 1.3 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 by the Department of Parks and Wildlife as being of most significant concern to the survival of remaining *D. masonii:*

1. Mining (direct removal);
2. Drying climate;
3. Inappropriate fire regimes;
4. Mining (threatening processes);
5. Weed invasion; and
6. Grazing.

### 1.3.1 Risk assessment

Each of the identified threatening processes was the subject of a risk assessment based on the Australian and international standard for risk management AS/NZS ISO 31000 (2009). The output of the risk assessment (Table 3) is used to identify management priorities and guide the allocation of resources towards recovery actions.

Risk assessment was also the basis for developing the management and mitigation measures applied through the approved "Extension Hill & Extension Hill North Environmental Management Plan", prepared to meet the conditions of Ministerial Statement No. 753 (in particular conditions 6 to 12 and 14 of Ministerial Statement No. 753).

The main elements of the risk assessment process involved:

- Identification of the potential threats, the cause of the threat, the potential impact on *D. masonii* and likelihood of occurrence in the absence of any controls resulting in a raw risk rating; and
- Estimating the likelihood of each threat occurring, the potential environmental consequences if it did occur and the subsequent determination of a controlled risk rating in context of the current controls;
- Consideration of recovery actions to further mitigate risk; and
- Re-estimating the likelihood of each risk event occurring and the potential environmental consequences if it did occur, and the subsequent determination of a final residual risk rating.

Further details of the risk assessment criteria are included in Appendix 10.4.

**Table 3. *Darwinia masonii* – risk assessment based on AS/NZS ISO 31000 framework**

This risk assessment uses a consequence **(C)** and likelihood **(L)** matrix (Appendix 10.4) to determine Inherent Risk **(IR)** which considers risk if there are no controls in place; Controlled Risk **(CR)** which considers the risk after application of existing controls and Residual Risk **(RR)** which considers the final residual risk level after the application of additional controls proposed in this recovery plan.

| **Risk Event (Threats)** | **Cause** | **Potential Impacts** | **C** | **L** | **IR** | **Existing Controls** | **C** | **L** | **CR** | **Additional Risk Mitigation Plan (Recovery Actions)** | **C** | **L** | **RR** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Direct removal of *Darwinia masonii* from the Mt Gibson Ranges habitat. | Approval of developments that require extensive clearing of native vegetation impacting a significant number of *D. masonii*. | Worst case scenario is that a level of clearing occurs that results in a step change in the IUCN Ranking of the species due to the level of direct removal (ie greater than 31% of species) | 2 | C | **4** | 1. Government regulation through a robust approvals process in which potential impacts are assessed including:<br>- Environmental Protection Act (Part IV - Environmental Impact Assessment)<br>- Environment Protection & Biodiversity Conservation Act<br><br>Approvals processes have specific mechanisms that can disallow or condition development in instances where the environmental impact is assessed as significant. | 2 | D | **8** | 1. Maintain and use seed/germplasm collections to ensure material with a broad genetic base is available for translocation and ongoing ex-situ conservation activities.<br>2. Develop and implement restoration program.<br>3. Promote awareness of *D. masonii*<br>4. Other actions specified in Section 4 of this Plan. | 2 | E | **12** |

| Risk Event (Threats) | Cause | Potential Impacts | C | L | IR | Existing Controls | C | L | CR | Additional Risk Mitigation Plan (Recovery Actions) | C | L | RR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2. Conditional environmental approval process including Ministerial Statements and offset programmes to manage the environmental impact of projects should they be approved. MS753 authorises a development envelope with 17% of the *D. masonii* population. In 2015 the proposed Iron Hill development envelope is under assessment as a PER.<br><br>3. Regulatory and proponent inspections, audits, monitoring and reporting. | | | | | | | |
| Drying climate | Natural phenomena | Extended drought periods negatively impact adult plants and recruits. | 2 | C | **8** | 1. Research to aid understanding of recruitment has been undertaken by BGPA (2010) and funded by Extension Hill Pty Ltd and Mount Gibson Mining.<br>2. Implement *D. masonii* condition monitoring program. | 2 | C | **8** | 1. Maintain seed and germplasm collections.<br>2. Develop restoration program as a contingency measure.<br>3. Other actions specified in Section 4 of this Plan. | 2 | C | **8** |

| Risk Event (Threats) | Cause | Potential Impacts | C | L | IR | Existing Controls | C | L | CR | Additional Risk Mitigation Plan (Recovery Actions) | C | L | RR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inappropriate fire regimes | Fire frequency increased as a result of mine site activities or lightning events. | Loss of large-scale adult population resulting in increased susceptibility of fire induced recruits. | 2 | C | **8** | 1. Fire risk is managed within the operational mining area and response capabilities exist to provide assistance in surrounding areas to manage large scale fire events. | 2 | D | **12** | 1. Additional controls not required at this time. Continue to implement fire management strategy as per existing controls. | 2 | D | **12** |
| Dust emissions and inadvertent disturbances such as cracking of rock faces.<br><br>(sometimes referred to as "Secondary Impacts of Mining") | Mining operations | Potential impact on plant health or reproductive biology that may lead to a decline in growth and recruitment rates. | 4 | B | **14** | **1.** Implementation of approved Environmental Management Plan and site procedures to monitor and minimise dust emissions.<br>2. Vegetation health monitoring adjacent to operational mining areas to examine potential effects. | 4 | D | **21** | 1. Continue to implement *D. masonii* condition monitoring program.<br>2. Continue to manage threatening processes from mining as per existing controls. | 4 | D | **21** |

| Risk Event (Threats) | Cause | Potential Impacts | C | L | IR | Existing Controls | C | L | CR | Additional Risk Mitigation Plan (Recovery Actions) | C | L | RR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weed invasion throughout *D. masonii* habitat | Increase movement of vehicles coupled with poor control over vehicle hygiene.<br><br>Increased activity of feral animals spreading weed species. | Potential to outcompete *D. masonii* resulting in poor recruitment and. | 4 | C | **18** | 1. Strict vehicle hygiene controls are in place for all vehicles and mobile equipment involved with mining operations.<br>2. The presence and distribution of weeds is surveyed annually in spring.<br>3. Weed eradication controls are applied in accordance with approved procedures within the mining areas and follow up inspections undertaken. | 4 | D | **21** | 1. Additional controls not required at this time. Continue to manage weed invasions as a threatening process from mining as per existing controls. | 4 | D | **21** |
| Grazing by introduced species (goats and rabbits) | Potential for increased size of populations. | Grazing may have a significant impact on growth and reproduction of *D. masonii*.<br><br>Repeated herbivory may impact on reproductive output. | 4 | C | **18** | 1. Coordination meetings with land managers in areas surrounding Mt Gibson Ranges on introduced species management undertaken.<br>2. Reporting of feral fauna sightings in mining areas to inform the implementation of controls.<br>3. Implementation of approved Environmental Management Plan. | 4 | D | **21** | 1. Protect plants from herbivory through the development and implementation of an adaptive management program to respond to increased herbivory from introduced species as necessary. | 4 | D | **21** |

| Risk Event (Threats) | Cause | Potential Impacts | C | L | IR | Existing Controls | C | L | CR | Additional Risk Mitigation Plan (Recovery Actions) | C | L | RR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 4. Water dams are securely fenced to prevent fauna access. | | | | | | | |

### 1.3.2 Drying climate

Drying climate rates as the most significant risk to the abundance and survival of *D.masonii* primarily because there is no control that can currently be applied that will reduce the risk of climate change occurring.

Mortality among mature (last burnt on or before 1969) *D. masonii* plants is rare in normal years, but drought in 2010 was found to contribute to a significant level of mortality (10%) among mature *D. masonii* plants marked for a pollination study on Mt Gibson South (BGPA, 2010).

*D. masonii* seedlings may also be less resilient to drought conditions than mature plants. BGPA (2010) reported that only 9% of the seedlings which were tagged within recruitment plots of an experimental fire in 2009 were still alive when these plots were revisited in October 2010. They stated "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" (p43). Thus a drying climate and associated drought conditions may reduce the successful establishment of subsequent seedling recruits.

Thus, there may be implications for the species (e.g. population size, demography, and breeding biology) if there is a significant increase in drying or a significantly greater frequency of dry years in the region.

### 1.3.3 Mining (direct removal)

The known habitat for *D. masonii* comprises ironstone formations that are also prospective for iron ore and under live mining leases. The current MGIOIP approval (MS 753) will result in approximately 2,100 adult plants of *D. masonii* being taken, which represents approximately 10% of the combined known population size.

Future mining and exploration operations have the potential to directly impact the conservation status of *D. masonii,* if it were to significantly reduce the total population size, genetic diversity or area of occupancy of the species.

### 1.3.4 Inappropriate fire regimes

*D. masonii* is long-lived and killed by fire (Armstrong and Associates, 2004; BGPA, 2010). However, *D. masonii* exhibits poor recruitment under normal seasonal conditions and has specific requirements for good recruitment

- Recruitment occurs after fire, and there is limited inter-fire recruitment; and
- Ground disturbance has anecdotally been recorded as inducing recruitment.

Natural regeneration of *D. masonii* after fire is restricted exclusively to germination from seed held in long-lived soil-stored seedbanks (BGPA, 2010). The majority of plants arising from seed germinate in a single cohort post-fire. Furthermore, the youngest age of plants to be recorded as flowering is at six years, but flower number at this age was very low. Large old plants with wide canopies produce the most flowers. Therefore, fire occurring too frequently within habitat colonised by *D. masonii* threatens the long term survival of the taxon.

Research has shown that:

- The seed has a physical and physiological dormancy process (removal/breakdown of fruit walls and stimulatory effect of smoke chemicals, respectively).
- Preliminary results of *in situ* seed burial trials indicate complex germination / dormancy strategies for this species, 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.
- The longevity of *D. masonii* seed in the soil-stored seed bank is unknown, and may be a factor which affects recruitment of the species in the longer term.

### 1.3.5 Mining (threatening processes)

Populations at Extension Hill South and Iron Hill North are closest to the Extension Hill mining operations approved under MS 753. Possible threatening processes were previously identified (DEC, 2008) to include dust, inadvertent disturbance such as cracking of rock faces, or negative effects on pollinator activity arising from habitat disturbance. Management actions were implemented to reduce the risk to the plants in the immediate vicinity of mining operations. Survivorship, health condition and height of *D. masonii* have been monitored annually since 2007. Analysis of this 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.*"

Future mining operations may have associated threatening processes to *D. masonii*. However, mitigation of these threatening processes (as per the Extension Hill mining operations) will maintain the risk as low.

### 1.3.6 Weed invasion

No significant weed invasion has been observed to date, although there are some 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 *D. masonii*. Weed invasion is also a potential threat to the integrity of the habitat critical to the species.

### 1.3.7 Grazing

BGPA (2010) found that grazing by vertebrates (presumed to be goats and rabbits) had a negligible impact on *D. masonii*. However, vertebrates including rabbits and goats are present within the Mt Gibson Ranges, and their impact on the vegetation varies between sites. Grazing was reported by BGPA (2010) as having a significant impact on *Lepidosperma gibsonii* at certain sites on the lower slopes of the range (Iron Hill and Iron Hill North only) and north east at a site (off range) near the emu-proof fence. In some areas *Lepidosperma gibsonii* co-occurs with *D. masonii* on the Mt Gibson ranges. The presence and abundance of faecal scats around the grazed *Lepidosperma gibsonii* indicated that grazing was attributable to rabbits and/or goats, and macropods. During the period of BGPA's research (2007 – 2010), and subsequent monitoring conducted by MGM, vertebrates have not been recorded as preferentially grazing *D. masonii*.

Grazing, however, is a potential threat to the integrity of the habitat of *D. masonii*. Grazing is also a potential future threat to *D. masonii* itself if the distribution and density of preferentially grazed plants decline within the habitat, resulting in *D. masonii* becoming relatively more palatable to vertebrates.

Since grazing pressure is not considered a static variable due to environmental or management factors, it remains a potential threat to the habitat and/or *D. masonii* individuals.

## 1.4 Broader biodiversity benefits

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

Two rare and eight priority flora taxa occur within 500 metres of *D. masonii* records (Table 4).

**Table 4. Conservation–listed flora species occurring within 500m of *D.masonii***

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

Six fauna listed under the *Wildlife Conservation Act* 1950 (WA), and five priority fauna have previously been recorded to occur within the range of *D. masonii* populations (Table 5).

**Table 5. 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) | T - Threatened (VU) | VU |
| *Merops ornatus* (Rainbow Bee-eater) | IA – Migratory birds protected under an international agreement* | Listed Marine<br>Listed Migratory (JAMBA)* |
| *Cacatua leadbeateri* (Major Mitchell's Cockatoo) | S – Other specially protected fauna | - |
| *Falco peregrinus* (Peregrine Falcon) | S – Other specially protected fauna | - |

| Species name | Conservation status (*Wildlife Conservation Act 1950*) | Conservation status (*Environment Protection and Biodiversity Conservation Act*) |
|---|---|---|
| *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 (western wheatbelt)) | Priority 4 | - |

* Migratory birds are protected under China-Australia Migratory Bird Agreement, Japan-Australia Migratory Bird Agreement, Republic of Korea-Australia Migratory Bird Agreement, and Bonn Convention

*D. masonii* occurs within the Priority 1 listed ecological community 'Mt Gibson Range vegetation complexes (banded ironstone formation)' (5 occurrences, 3,216 hectares total). For a description of Priority Ecological Community (PEC) categories see DEC (2010).

No negative effects of the recovery actions on other conservation significant taxa and the priority ecological community for *D. masonii* have been identified during the period when the Interim Recovery Plan was implemented. Recovery actions will continue to be assessed to ensure there are no negative effects on other conservation significant taxa and the PEC.

# 2 Recovery objectives and criteria

## 2.1 Plan objective

The objective of this plan is "*to maintain, and ultimately improve, the conservation status of D. masonii such that its conservation status is more secure in the Mt Gibson area*" (Ministerial Statement 753).

## 2.2 Recovery criteria

**Criteria for success:**

This recovery plan will be deemed successful if, over the term of the plan, all of the following are achieved:

1. The number of *in-situ* mature individuals in areas of known occupancy, outside of areas approved for disturbance under Ministerial Statements remains stable[2] or increases.

2. The conservation category of the species remains at the current status or improves.

**Criteria for failure:**

This recovery plan will be deemed unsuccessful if, over the term of the plan, any of the following occur:

1. The total number of all *in-situ* mature individuals in areas of known occupancy, outside of areas approved for disturbance under Ministerial Statements has decreased by more than 20% beyond its natural variability* as a result of effects from threats identified in section 1.3 ;

2. The conservation status meets IUCN criteria for listing at a higher threat category than the status (at the time of publication of this Recovery Plan).

* Natural variability will be assessed through regular monitoring as described in Section 4.5 and 4.9

[2] Stable means number of mature individuals plus or minus fifteen per cent.

# 3 Past and existing recovery actions

Parks and Wildlife has reviewed the relevance and effectiveness of the 2008 *Darwinia masonii* Interim Recovery Plan (IRP; DEC, 2008) in the 2014 *Darwinia masonii* Review Paper (Parks and Wildlife, 2014). The IRP identified eleven recovery actions associated with the taxon, listed below:

1. Coordinate recovery actions and liaise with stakeholders
2. Continue implementation of the *Darwinia masonii* research programme
3. Establish and implement *Darwinia masonii* condition monitoring programme
4. Implement Fire Management Strategy
5. Manage threatening processes of mining
6. Manage inappropriate grazing pressure on *Darwinia masonii*
7. Translocation trials
8. Maintain adequate seed/germplasm collections to ensure material with a broad genetic base is available for translocation and on-going ex situ conservation
9. Conduct further surveys and report any new populations of *Darwinia masonii*
10. Promote awareness of *Darwinia masonii*
11. Review ranking of the species and the need for a full Recovery Plan

Further detail relating to these actions, an evaluation of their implementation and related recommendations are provided in Table 6 .

**Table 6. Past recovery actions in the *Darwinia masonii* IRP (DEC, 2008), evaluation of their implementation, and related recommendations.**

| Part of recovery action | Timing | Responsibility | Evaluation of recovery action implementation | Recommendation |
|---|---|---|---|---|
| **3.1 Coordinate recovery actions and liaise with stakeholders** | | | | |
| Continue to coordinate the implementation of recovery actions for *Darwinia masonii* | Ongoing until 2012 | GDTFRT | • GDTFRT have not coordinated the implementation of recovery actions for *Darwinia masonii* | This action is carried over in this Plan (Section 4.1).<br><br>Responsibilities for some aspects have been re-allocated. |
| Ensure implementation of research, management and recovery actions for *Darwinia masonii* in consultation with Parks and Wildlife, DoE, BGPA, Geraldton District Threatened Flora Recovery Team, relevant land managers and indigenous groups. | | MGM & EHPL | • Research as outlined in recovery action 2 has been implemented and completed.<br>• Implementation of the majority of management and recovery actions for *Darwinia masonii* has been undertaken.<br>• Consultation has been undertaken with a number of the stakeholders. This has been enhanced through employment of a Conservation Officer at Parks and Wildlife in August 2013. | |
| Annual progress report will be produced by 31 March each year. | | Parks and Wildlife, GDTFRT, MGM & EHPL | • An annual progress report has not been produced. MGM and EHPL reported on the outcomes of research and monitoring of this species as part of their broader annual environmental reports. | |
| **3.2 Continue implementation of the *Darwinia masonii* research programme** | | | | |
| A comprehensive programme of research into:<br>• conservation genetics;<br>• population demography;<br>• breeding biology;<br>• population viability analysis;<br>• environmental interactions and plant health;<br>• restoration and translocation; and,<br>• *ex situ* conservation of *Darwinia masonii* is currently being implemented and is ongoing. The initial research programme will extend to December 2010, at which time the direction of future research will be reviewed. The nature of some of the research is longer term (5 years minimum). | 2007 – 2010 (initially) | MGM, EHPL, BGPA & Parks and Wildlife (ex situ conservation only) | • The initial research programme was completed and was submitted by BGPA to MGM and EHPL in October 2010 in the form of a report entitled "*Darwinia masonii* and *Lepidosperma gibsonii* Conservation and Restoration Research. An integrated research program into the *ex situ* and *in situ* conservation, restoration and translocation requirements of *Darwinia masonii* and *Lepidosperma gibsonii* May 2007 – June 2010".<br>• The findings of BGPA's (2010) research have provided much of the information in Section 1 (the Background) of this plan.<br>• Recommendations on the direction of future research were provided by BGPA (2010).<br>• A joint research project investigating soil plant atmosphere interactions and their influence on mine waste cover system performance commenced in 2014. | Further research to benefit recovery of *Darwinia masonii* is included in this plan (Sections 4 and 5).<br><br>This draws on the recommendations of BGPA's (2010) initial research. |

| Part of recovery action | Timing | Responsibility | Evaluation of recovery action implementation | Recommendation |
|---|---|---|---|---|
| **3.3 Establish and implement *Darwinia masonii* condition monitoring programme** | | | | |
| Monitoring factors such as weed invasion, grazing, habitat degradation, population stability (expansion or decline), pollinator activity, seed production, recruitment, and longevity will be monitored. Rare Flora Report Forms will be prepared for monitoring undertaken. | 2008 – 2012 | GDTFRT, Parks and Wildlife | • Populations have not been monitored by GDFRT or Parks and Wildlife regularly. TPFL population 2b was inspected by Parks and Wildlife to confirm its presence and location in September 2013, and a partial count of numbers undertaken. Intermittent brief inspections of certain populations were undertaken by Parks and Wildlife up until 2007, but none were conducted again until October 2013. | This action is carried over in this Plan (Sections 4.5 and 4.9).<br><br>Responsibilities for some aspects have been re-allocated. |
| The condition of the population not directly impacted by mining will be monitored for any indirect impacts from mining, of which the greatest risk may be excessive dust deposition, and other potential threats such as grazing by introduced or native animals and weeds that may impact on plant condition. A representative subset of 715 individual plants (5% of total pre—mining adult population) will be monitored in detail annually. | | MGM & EHPL | • The condition of populations of *Darwinia masonii* not directly impacted by mining approved under MS753 has been monitored annually since 2007. A total of 653 plants were included in the annual monitoring program in April 2013 (MGM and EHPL, 2013). Some of these were dead and some could not be relocated, which resulted in a total of 511 plants which were scored, down from 569 in 2011. In 2013, plant height (or length for prostrate plants), reproductive status, plant age, plant condition and seedling recruitment and mortality were recorded.<br>• Additional monitoring plots were established in the subsequent survey, conducted in November 2013, to ensure the target numbers were met. A total of 881 plants were scored (773 of these were alive) (J Sackmann 2014, pers. comm., 11 February). | |

| Part of recovery action | Timing | Responsibility | Evaluation of recovery action implementation | Recommendation |
|---|---|---|---|---|
| Ambient dust monitoring will be undertaken on a monthly basis in permanent quadrats to assess dust deposition on *D. masonii*. Populations closest to the mine (e.g. Extension Hill South) will be monitored monthly to assess any changes in condition prior to evidence of acute stress or mortality. Visual inspections of the populations closest to the mine (e.g. Extension Hill South) will be undertaken weekly. Populations located further away from the mine will be inspected quarterly. The results of the monitoring program will be used to guide subsequent management of the species. | | MGM & EHPL | • TPFL population 4 is located closest to mining activities on Extension Hill South and is monitored monthly by MGM to assess detectable changes in condition prior to evidence of acute stress or mortality. TPFL population 6 is located on Mt Gibson is monitored as a control for comparison. At each plot, a photograph is taken, and plants are given a health score. Comments recorded at the plots include evidence of grazing and weed invasion.<br>• Ambient dust monitoring is also 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). 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, 2008).<br>• Visual inspection at TPFL population 4, closest to the mine on Extension Hill South is undertaken weekly by MGM. At each plot, a photograph is taken, and plants are given a health score. Comments recorded at the plots include evidence of grazing and weed invasion. | This action is modified and carried over in this Plan (Section 4.5). |
| The results of the monitoring program will be used to guide subsequent management of the species. | 2008 – 2012 | MGM, EHPL, Parks and Wildlife & GDTFRT | • Comprehensive analysis of condition monitoring data has been conducted by Astron Environmental Services (2014a). Generalised estimating equation, generalised linear models and permutation-based multivariate analysis of variance tests were used to analyse the data. Astron Environmental Services (2014a) concluded that "*there was no evidence showing that health condition or survivorship was impacted by mining activity*". | The requirement for comprehensive analysis of historical and future condition monitoring is captured in Section 4.5. It is expected that these results will be used to guide subsequent management of the species, and will be considered in the review of the Plan (Section 4.12) |

| Part of recovery action | Timing | Responsibility | Evaluation of recovery action implementation | Recommendation |
|---|---|---|---|---|
| The research program will investigate and develop measures to assess plant health and will collect detailed demographic data from approximately 2% of the population in long term monitoring plots as part of the research program. | | MGM, EHPL, Parks and Wildlife & GDTFRT | • BGPA collected detailed data in order to complete the initial research program as outlined in recovery action 2. BGPA (2010) recommended ongoing annual monitoring of all plants in permanently marked plots where individual plants should be tagged and measured. Additional variables recommended for collection were: survival, recruitment (new plants tagged and recorded as found), health, herbivory, infructescence production, and growth of seedlings and smaller plants.<br>• Demographic data from *D. masonii* plants in all permanently marked plots is collected annually by MGM. These individual plants are tagged and measured as follows: survival and health score, recruitment (new plants are tagged and recorded as found), and notes about herbivory. Information is also collected relating to infructescence production, and growth of seedlings and smaller plants. | This action is carried over in this Plan (Section 4.5). |
| **3.4 Implement Fire Management Strategy** | | | | |
| An Environmental Management Plan and fire management procedures are being developed that detail the frequency and intensity of fires and control measures necessary to prevent inappropriate fires which may impact on the species directly, or its habitat. | Ongoing for life of mine | MGM & EHPL | • Mt Gibson Ranges and the habitat of *Darwinia masonii* are currently under a no burn fire management regime. Any fires which would occur on the ranges are wildfires or unplanned man made fires. There has been no unplanned fire in habitat of *Darwinia masonii* since 2008.<br>• An experimental fire within *Darwinia masonii* TPFL population 2 was conducted by BGPA on 12 May 2009, and monitoring of recruitment in plots within the fire boundary was subsequently undertaken (BGPA, 2010). This experiment confirmed that *D. masonii* germinates strongly after fire (see Section 1.1.3).<br><br>An Environmental Management Plan and Fire Management Procedures have been developed and adopted. | This action is carried over in this Plan (Section 4.6).<br>An assessment of controlled burning as a benefit to recovery will need to be made during regeneration trials, and implemented (if there is a benefit) through a recruitment strategy as a component of a broader restoration program (Section 4.2). |
| **3.5 Manage secondary impacts of mining** | | | | |
| Implement Environmental Management Plan and associated procedures. | Ongoing for life of mine | MGM & EHPL | • This action has been implemented. | This action is carried over in this Plan (Section 4.7). |

| Part of recovery action | Timing | Responsibility | Evaluation of recovery action implementation | Recommendation |
|---|---|---|---|---|
| **3.6 Manage inappropriate grazing pressure on *D. masonii*** | | | | |
| Undertake condition monitoring | Ongoing for life of mine | MGM & EHPL | • Grazing by introduced animals (goats and rabbits) has been assessed as part of monitoring the condition of *D. masonii* (see Section 3.3). Grazing has not been identified as having a significant effect on *D. masonii*.<br>. | This action is carried over in this Plan (Section 4.5).<br>The impacts of grazing on the integrity of *Darwinia masonii* habitat have not been monitored. It will be necessary for habitat health to be recorded at established plots during the annual condition monitoring program. This will enable assessment of the impacts of grazing on the habitat of *D. masonii*, and implementation of actions to mitigate grazing impacts. |
| Implement Environmental Management Plan and associated feral or other introduced animal procedures | | MGM & EHPL | • This part of the recovery action is being implemented. | |
| **3.7 Translocation trials** | | | | |
| Describe biotic and abiotic environments and habitat requirements. Trial *in-situ* planting methods. | 2007 – 2010 (initially) | MGM, EHPL & BGPA | • BGPA (2010) described biotic and abiotic environments and habitat requirements for *D. masonii* and used a species distribution model to identify localities for possible *D. masonii* translocation sites (Sections 1.1.3 and 1.2).<br>• *In situ* planting methods using cuttings have been trialled at Mt Gibson on four differing field soil substrates (BGPA, 2010; and Section 1.1.5). In total, 780 *Darwinia masonii* plants grown from cuttings were planted in July/August 2009 at the sites (3 plots per site with 65 plants per plot). The locations of the sites are provided in BPGA's report (2010). After 9 months, by April 2010, differences in success were evident, with the only successful plantings being on BIF rock and BIF gravel sites. BGPA (2010) | BGPA's (2010) recommendation for further translocation trials to investigate variation in BIF substrate and soil depth is captured in Section 4.2 of this Plan. |

| Part of recovery action | Timing | Responsibility | Evaluation of recovery action implementation | Recommendation |
|---|---|---|---|---|
| | | | suggested that texture, gravel/rock content, patterns of moisture content and Total Nitrogen may be the key soil properties to consider in selection of translocation sites. Plants on clay and sand sites to the east and west of the Mt Gibson Ranges, respectively, were not successful. The BIF rock and BIF gravel sites have not been re-visited to establish whether any plants from this trial survive.<br>• BGPA (2010) recommended further research to investigate variation of composition of BIF rock and BIF gravel substrate, and varying degrees of soil depth and rockiness.<br>• Irrigation during establishment of translocations may improve growth and survival of seedlings (BGPA, 2010). A preliminary planting trial of 206 *D. masonii* plants grown from cuttings and planted in a ripped drill pad at Iron Hill East was fenced to exclude herbivores and irrigated for an hour at a time twice a month over the first two summers. Twenty additional plants were planted outside of the fenced irrigated area. Two (10%) of the unwatered plants survived to 2010, while 89% of the watered plants survived the same period. Half of the plants within the watered plot flowered within their first year, and all had tripled in size in the first 18 months. BGPA (2010) reported no evidence of mammalian herbivory on *Darwinia masonii* during their three year research project undertaken between 2007 and 2010. Therefore, the improved growth and survival of the seedlings in this planting trial was attributed to the irrigation that they received. This plot was re-visited in March 2014 and 174 plants (80%) within the fenced plot were still alive, despite having not been watered for 7 years (Eco Logical Australia, 2014). The translocated plants in the trial and not watered outside the fenced area had all died, however second generation seedlings were observed growing outside of the fenced plot. | |

| Part of recovery action | Timing | Responsibility | Evaluation of recovery action implementation | Recommendation |
|---|---|---|---|---|
| Identify critical parameters for the long-term viability of re-established populations of *Darwinia masonii* and related species | | MGM, EHPL & BGPA | • BGPA's (2010) species distribution model predicted *D. masonii* to potentially occur broadly across the Mt Gibson ranges with a high probability (60-75 %) of occurrence (BGPA, 2010; Section 1.1.3; and, Figure 4). They recommended that mapping of soil or regolith data for the region may assist with refining the distribution model to improve understanding and predictions of the habitat and restoration requirements for *D. masonii*.<br>• It appears from the planting trials conducted by BGPA (2010) that *D. masonii* has broad habitat requirements on BIF sites, with substrate comprising BIF rock and BIF gravel. Irrigation during establishment of translocations may improve growth and survival of seedlings. Other parameters (e.g. pollination, seed production, seed viability, seed dispersion), which had not been gauged because of the relatively short length of time over which the BGPA research took place, may be critical for the long-term viability of re-established populations. | The knowledge gained from the habitat modelling and planting trials (BGPA, 2010) have assisted in improving knowledge of parameters which may be critical for the long-term viability of re-established populations of *D. masonii*. Further research to benefit recovery (Section 5) and translocations (Section 4.2) should continue to assist with identification of these parameters and refining those that are critical. |
| Derive quantitative completion criteria which demonstrate maintenance of viable population dynamics and resilience in *Darwinia masonii* | | MGM, EHPL & BGPA | • Quantitative completion criteria which demonstrate maintenance of viable population dynamics and resilience in *D. masonii* have been derived in translocation proposals (currently being assessed by DPaW). | This action is carried over in this plan (Section 4.2). |

| Part of recovery action | Timing | Responsibility | Evaluation of recovery action implementation | Recommendation |
|---|---|---|---|---|
| **3.8 Maintain adequate seed/germplasm collections to ensure material with a broad genetic base is available for translocation and on-going ex situ conservation** | | | | |
| Maintain adequate seed/germplasm collections | Ongoing until 2012 | MGM & EHPL through BGPA | • *Darwinia masonii* is able to be successfully cultivated and a stock of 56 genotypes from the Extension Hill mine footprint is in cultivation at Nuts About Natives (NAN), a specialist native plant nursery (B Croxford 2015, pers. comm; 7 April). Cuttings were collected (under DRF collection permits held by EHPL and BGPA) from 300 genotypes of *D. masonii* from within the mine footprint on Extension Hill and transported to NAN in October 2008. After 3 months, 12% of the total cuttings (385 *Darwinia masonii* cuttings) from 50% of the genotypes (150 different genotypes) had successfully initiated.<br>• The intention of the germplasm collection was for clones of the *Darwinia masonii* genotypes from Extension Hill and Extension Hill North to be maintained as tube stock in two collections, with three clones of each genotype in each collection. However, some clones have not grown well and it has been necessary to pot up and maintain plants as new cuttings have not always been successful or numbers are low (B Croxford 2014, pers. comm., 27 January). Some clones are growing well with more than three clones per collection. The plants and clones are kept on unshaded external benches, regularly monitored, and watered at moderate intervals. The genotypes are subcultured annually from the parent stock. Flowers from the clones have been manually removed and disposed of before maturation, but some did reach maturation in 2013, and the seed has been collected and stored on site (B Croxford 2014, pers. comm., 27 January).<br>• The 56 genotypes of *Darwinia masonii* currently held in parent stock (B Croxford 2015, pers. comm., 13 March) are not all healthy. The leaf tips of many clones are yellowed, and it is possible that this is due to a physical or chemical factor. This observed response to nursery conditions was also reported by BGPA (2010), which found that while *Darwinia masonii* cuttings survive and flower, they have not done so vigorously. | This action is carried over in this Plan (Section 4.3). Preservation of genetic material is essential to guard against extinction of the species if the wild populations are lost. The action has been worded to ensure this ex situ conservation, as well as ensuring that material is also available for use in translocation programs. |

<table>
<tr><th>Part of recovery action</th><th>Timing</th><th>Responsibility</th><th>Evaluation of recovery action implementation</th><th>Recommendation</th></tr>
<tr><td></td><td></td><td></td><td>
<ul>
<li>The New Holland honeyeater and the Western Spinebill have been observed pollinating D. masonii flowers. Seeds (80% viability) have been collected from the nursery plants since 2013 (B Croxford 2015, pers. comm., 13 March).</li>
<li>A small number of genotypes of Darwinia masonii are still maintained in glasshouses at the Botanic Gardens and Parks Authority for experimental purposes.</li>
<li>While propagation of live plant material from wild collections and nursery stock may pose the most cost effective approach for the short-medium term storage and production of plants for restoration purposes, BPGA (2010) recommended further research into seedling production as this appears promising and may provide a preferable approach to providing a genetically diverse and numerous source of restoration plants. Drawbacks to the use of clones for population restoration were outlined by BGPA (2010).</li>
<li>Collection and storage of seed have been reported by BGPA (2010), and Landcare Services (2007; and, 2009). Western Botanical (2014) hold 1,024 g of D. masonii seed in storage.</li>
<li>Parks and Wildlife's Threatened Flora Seed Centre currently has three collections of D. masonii seed (Table 7):</li>
</ul>
Table 7. Darwinia masonii seed collections held by Parks and Wildlife's Threatened Flora Seed Centre
<table>
<tr><th>Accession</th><th>Collection date</th><th>Location</th><th>TPFL Pop</th><th>Seeds / fruit in storage</th><th>Germination (%)</th></tr>
<tr><td>01502</td><td>11/11/2004</td><td>Extension Hill North</td><td>3</td><td>466 seed</td><td>90%</td></tr>
<tr><td>01503</td><td>11/11/2004</td><td>Mt Gibson South</td><td>7</td><td>1634 fruit</td><td>Not yet tested</td></tr>
<tr><td>01519</td><td>11/11/2004</td><td>Mt Gibson</td><td>6</td><td>4941 fruit</td><td>Not yet tested</td></tr>
</table>
</td><td></td></tr>
</table>

| Part of recovery action | Timing | Responsibility | Evaluation of recovery action implementation | Recommendation |
|---|---|---|---|---|
| **3.9 Conduct further surveys and report any new populations of *D. masonii*** | | | | |
| Any new populations of *Darwinia masonii* that may be opportunistically located will be reported to Parks and Wildlife to ensure Parks and Wildlife has accurate data on the species. | Ongoing until 2012 | MGM, EHPL, BGPA, Parks and Wildlife, GDTFRT | • The most recent and comprehensive survey was undertaken by Eco Logical (2014) was completed during 2014 (four trips between May and October 2014). The census recorded 20,965 individuals of *D. masonii*, comprised of 19,132 mature individuals, 1,580 juveniles, 188 seedlings and 65 senescent individuals. This census presents a significant increase to the recorded abundance of *D. masonii* at the Mt Gibson Ranges.<br>• A broader regional survey for *Darwinia masonii* was undertaken and completed in June 2014 (Maia, 2014b). A survey of nine regional areas covering 1,032 ha occurred within 55 km of the Mt Gibson Ranges. *Darwinia masonii* was not located in any of the nine regional areas (Maia, 2014b). | This action is carried over in this plan (Section 4.10). |
| **3.10 Promote awareness of *Darwinia masonii*** | | | | |
| Promote need for protection through poster displays and local print and electronic media | Ongoing | Parks and Wildlife, GDTFRT | • This action has not yet been implemented | This action is carried over in this Plan (Section 4.4). |
| Continue environmental inductions and Environmental Handbook dissemination | Ongoing | MGM & EHPL | • This action is being implemented | |
| **3.11 Review ranking of the species and the need for a full Recovery Plan** | | | | |
| In accordance with Condition 6.3 of Ministerial Statement 753, the relevance and effectiveness of the plan (DEC, 2008) will be reviewed within 4 years of the commencement of ground disturbing activities and the plan updated as necessary. The ranking of the species (currently Vulnerable) will be reviewed as part of the review of the IRP. | June 2014 | MGM, EHPL, Parks and Wildlife, GDTFRT, in association with BGPA | • This action has commenced, and has resulted in the preparation of this Recovery Plan.<br>• A review of the IUCN status of *D. masonii* in relation to the cumulative impacts from the MGIOMIP and the proposed Iron Hill development found that there would be no change in its IUCN ranking (Globe Environments, 2014).<br>• A review of the ranking of the species will be undertaken by DPaW. | It will be necessary to Review conservation status of the species (Section 4.11) and Review this recovery plan. (Section 4.12). |

# 4 Future recovery actions

The EPBC Act requires that this plan specify the recovery actions necessary to achieve the objective of the plan. There is a requirement that the actions identified in the plan stop the decline of, and support the recovery of *D. masonii*, so that its chances of long term survival in nature are maximised.

The recovery actions have been developed in response to the threatening processes outlined in Section 1.3. They have been formulated to achieve the objective of this plan, and are based on the outcomes of the research and the implementation of the *D. masonii* IRP to date, as well as aspects of the conditions of MS753 pertinent to *D. masonii*. They are:

1. Coordinate recovery actions and liaise with stakeholders;
2. Develop and implement restoration strategy
3. Maintain and use seed/germplasm collections to ensure material with a broad genetic base is available for conservation
4. Promote awareness of *Darwinia masonii*
5. Implement *Darwinia masonii* condition monitoring program
6. Implement fire management strategy
7. Manage threatening processes of mining
8. Protect plants from herbivory
9. Report any new occurrences of *Darwinia masonii*
10. Review conservation status of the species
11. Review this recovery plan.

A summary of risk ratings for *D. masonii* for each of the threatening processes before and after application of corresponding recovery actions is shown in Table 8 (as derived in Table 3). These ratings relate to the magnitude of the risk to the species and the ability to manage that risk over the 10 year timeframe of this Plan.

Key recovery actions have been developed to mitigate risks as part of the IRP and will be continued in this Plan.

Recovery actions that are not directly related to threatening processes, but which are important for efficient and effective implementation of the Plan are:

- Coordinate recovery actions and liaise with stakeholders;
- Monitor populations;
- Report and protect existing and any new occurrences of *D. masonii*;
- Review assigned conservation status of the species; and,
- Review this plan and assess the need for an updated Recovery Plan.

Budget allocations relating to recovery actions are listed in Table 9.

**Table 8. Summary of inherent, controlled and residual risks to the survival of *Darwinia masonii***

| Risk Event (Threats) | Inherent Risk | Controlled Risk^ | Recovery Actions | Residual Risk |
|---|---|---|---|---|
| Direct removal of *Darwinia masonii* from areas outside the currently approved development envelope. | **High (4)** | **Medium (8)** | 1. Maintain and use seed/germplasm collections to ensure material with a broad genetic base is available for translocation and ongoing ex-situ conservation activities.<br>2. Develop and implement restoration program.<br>3. Promote awareness of *D. masonii*<br>4. Other actions specified in Section 4 of this Plan. | **Medium (12)** |
| Drying climate | **Medium (8)** | **Medium (8)** | 1. Maintain seed and germplasm collections.<br>2. Develop restoration program as a contingency measure.<br>3. Other actions specified in Section 4 of this Plan. | **Medium (8)** |
| Inappropriate fire regimes | **Medium (8)** | **Medium (12)** | 1. Additional controls not required at this time. Continue to implement fire management strategy as per existing controls. | **Medium (12)** |
| Dust emissions and inadvertent disturbances such as cracking of rock faces.<br><br>(sometimes referred to as "Secondary Impacts of Mining") | **Medium (14)** | **Low (21)** | 1. Continue to implement *D. masonii* condition monitoring program.<br>2. Continue to manage threatening processes from mining as per existing controls. | **Low (21)** |
| Weed invasion throughout *D. masonii* habitat | **Medium (18)** | **Low (21)** | 1. Additional controls not required at this time.<br>2. Continue to manage weed invasions as a threatening process from mining as per existing controls. | **Low (21)** |
| Grazing by introduced species (goats and rabbits) | **Medium (18)** | **Medium (21)** | 1. Protect plants from herbivory through the development and implementation of an adaptive management program to respond to increased herbivory from introduced species as necessary. | **Low (21)** |

*The time frame to develop and implement translocations is within the term of the Plan (10 years) however the time frame to meet completion criteria for a translocation is much longer and requires establishment of a viable self-sustaining population (usually of at least 200 mature plants).

**Implementation of a recruitment strategy may only just have begun after 10 years as small scale trials testing various scenarios will need to be undertaken prior to this with a number of years of monitoring post-trial. This rating is expected to be reduced in the longer term.

^Taking into account past and present recovery actions.

Recovery actions that are not directly related to threatening processes, but which are important for efficient and effective implementation of the Plan and achievement of its objective are:

- Coordinate recovery actions and liaise with stakeholders;
- Monitor populations;
- Report and protect existing and any new occurrences of *D. masonii*;
- Review assigned conservation status of the species; and,
- Review this plan and assess the need for an updated Recovery Plan.

Budget allocations relating to recovery actions are listed in Section 8.

## 4.1 Coordinate recovery actions and liaise with stakeholders

Parks and Wildlife will coordinate the management of threatening processes (recovery actions) in relation to *D. masonii*.

MGM and EHPL will consult with and seek advice from Parks and Wildlife during implementation of the Recovery Plan for *D. masonii*.

As part of their broader conservation objectives, Parks and Wildlife will:

- Include information on progress of this Plan in annual reports to Parks and Wildlife's Corporate Executive and funding bodies.

**Actions:**

- Coordinate recovery actions, and liaise with stakeholders (Parks & Wildlife).
- Implement the Recovery Plan (Parks & Wildlife, EHPL and MGM).
- Provide an annual report on the Plan's progress to Parks and Wildlife's Corporate Executive and funding bodies (Parks & Wildlife).

**Responsibility:** Parks & Wildlife, EHPL and MGM

**Timing**: ongoing; annually for the report

| | |
|---|---|
| **Commencement date:** | On adoption of the Recovery Plan |
| **Completion date:** | Life of Recovery Plan |

## 4.2 Develop and implement restoration strategy

Condition 6.1.4 of MS753 requires that the proponent develop measures to offset the direct impacts of the proposal on the local population of *D. masonii* by regeneration, re-establishment or translocation of additional plants or sub-populations on suitable un-impacted areas of banded ironstone formations in the Mt Gibson area. This recovery action captures all aspects of this condition.

**Translocations**

Translocations undertaken to fulfil the requirements of condition 6-1-4 are those which meet the requirements of the condition, as well as fulfilling the objective of this Plan and of establishing a self-sustaining population(s) of 200-250 plants.

BGPA modelled the distribution of *D. masonii* against spatially mapped characteristics (see Sections 1.1.3 and 1.1.5, and Figure 4). The model identified habitat that may be suitable to the species, but is not currently inhabited by it. The distribution of *D. masonii* may be limited by unknown factors, such as regolith (soil depth, underlying rock structure), longer-term fire history patterns, or other ecological factors (e.g. seed dispersal distances) which may refine potential habitat mapping. The predicted habitat is shown in Figure 4.

The knowledge gained from the habitat modelling (BGPA, 2010) and translocation trials, which have already been conducted (BGPA, 2010) will assist in identifying suitable habitat for *D. masonii* translocations, both in suitable areas of the Mt Gibson Range, other suitable habitat, and in the rehabilitation of areas disturbed by mining.

Future translocations should consider an allowance for irrigation of translocated plantings as this will increase the translocation success rate.

Propagation of live plant material from wild collections and nursery stock are likely the most cost effective approach for the short-medium term production of plants for restoration purposes. Seed germination and seedling establishment under glasshouse or field conditions may also provide an approach for a genetically diverse and numerous sources of restoration plants (BGPA, 2010).

Information on the translocation of threatened plants in the wild is provided in Parks and Wildlife's Policy Statement No. 29 *Translocation of Threatened Flora and Fauna* (CALM 1995), and the Australian Network for Plant Conservation translocation guidelines (Vallee et al. 2004). Long-term monitoring of translocations will be included in all Translocation Proposals.

**Rehabilitation**

Mycorrhizal formation is potentially important for restoration success of *D. masonii* (e.g. for seeding survival and growth rate, as has been shown for a variety of VAM and ECM-forming species). This should be further investigated in comparative restoration trials, in particular whether or not restoration-planted seedlings are spontaneously able to form mycorrhizal associations in restoration surfaces, or whether inoculation is required or beneficial.

A research project, funded by MGM investigating soil plant atmosphere interactions and their influence on mine waste cover system performance is currently underway. Earthworks and plot preparation were completed in June 2014. Among other objectives, this research will investigate how topsoil thickness (comprised of a 2:1 waste rock: topsoil mix) and rooting depth influence the physiological performance of the taxa in the project. A translocation program has been approved (2015) to use *D. masonii* in the trials, however, the research is now well underway and propagation of sufficient *D. masonii* plant material will take 12 months. The logistics of getting approval to implement this trial may result in delays. .

These trials (and potentially others) will inform whether or not *D. masonii* can be used in future and broadscale rehabilitation of waste landforms in the Mt Gibson Range. Waste landforms may provide suitable habitat for the re-establishment of the species within the local geographic area in which it naturally occurs.

**Recruitment**

Fire has been recognized as an effective means of germinating *D. masonii* in the wild. The role of other natural disturbance events (physical or drought) in promoting recruitment of *D. masonii* have not been established and should be investigated (i.e. soil disturbance and drought response of populations). Records will need to be maintained for future research. Any regeneration trials involving fire may need to be undertaken in conjunction with weed control.

**Actions:**

- Prepare *D. masonii* Restoration Strategy and program (inclusive of translocation, regeneration and re-establishment) that complies with Parks and Wildlife policy. The restoration strategy and program includes offsetting the direct impacts of proposal/s on local population/s of *D. masonii* through translocation on suitable areas of the Mt Gibson Range (EHPL & MGM, 2014).
- Commence implementation of Restoration Strategy to maintain the integrity of the genetic diversity of *D. masonii* (EHPL & MGM, 2015).
- For rehabilitated landforms, further assessment of patterns of BIF rock and BIF gravel substrate, and varying degrees of soil depth and rockiness and growing media required for establishment of *D. masonii* will be made (taking into consideration landform stability requirements)(EHPL & MGM, 2015-2017).
- Monitor the survival and sustainable establishment of the plants remaining from the preliminary planting trial of *D. masonii* at the disused drill pad on Iron Hill East (EHPL & MGM, 2014-2017).
- Monitor the survival of the plants from the planting trial established on the BIF rock and BIF soil substrates north of Extension Hill (EHPL & MGM, 2014).
- Identify parameters for the long-term viability of re-established populations of *D. masonii* (EHPL & MGM, ongoing).
- Monitor translocations and supplement them as necessary (EHPL & MGM, ongoing).
- Monitor and report on the implementation of the Restoration Strategy (EHPL & MGM, 2015-2018).
- Review and update Restoration Strategy in order to meet criteria for this Plan (see Section 2.2, EHPL & MGM).

**Responsibility**: MGM, EHPL

**Timing**: Ongoing

| | |
|---|---|
| **Commencement date:** | November 2014 |
| **Completion date:** | Life of MGIOMIP, and subsequent mine closure |

## 4.3 Maintain and use seed/germplasm collections as a broad genetic base for conservation

A review of the seed held in storage, its quality, and the populations from which it originates, is necessary.

Preservation of genetic material is essential to guard against extinction of the species if the wild populations are lost. Suitable quantities of viable seed representing the genetic diversity of the species will be collected and maintained at the Threatened Flora Seed Centre (TFSC). This should be made available for on-going *ex situ* conservation and for future use in translocation programs. Quantities of seed used in translocation programs will be supplemented with seed from the same source.

The optimal time for seed collection is late October to early November (Landcare Services, 2007; BGPA, 2010).

Maintenance of the *D. masonii* germplasm collection, which has a representation of the genotypes cleared for the MGIOMIP footprint, should continue until such a time as viable populations preserving the genetic diversity

of the pre-mining *D. masonii* population are re-established, or sufficient seed from target populations 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 (including TPFL 2 and 3) cleared during mining activities under Ministerial Statements.

**Actions**:

- Develop a seed collection plan to identify representative species in the PEC, their composition and abundance required to meet objectives (to be determined) for collecting the seed in the first place (EHPL & MGM, 2014).
- Collate and annually check records of retained seed stock in storage (EHPL & MGM, 2014).
- One-off viability test of retained seed stock in storage (EHPL & MGM, 2015)
- Targeted seasonal collection of seeds from key Mt Gibson Ranges populations (late October to early November) to give seed representation (EHPL & MGM, late Spring 2015-2016).
- Propagation of live *D. masonii* plants from wild collection seed stock (2015-2017) for the purposes of translocation (Section 4.2; EHPL & MGM).
- Provision of nominated seed samples to the Threatened Flora Seed Centre (EHPL & MGM, 2015-2016)
- Review adequacy of *ex situ* collection to inform future actions (EHPL & MGM, 2017)
- Supplementation of seed in storage (upon identification of inadequate stock levels (EHPL & MGM, 2018 – 2019)

**Responsibility**: MGM and EHPL, upon advice from Parks & Wildlife

**Timing**: applicable seasonal timing for collection and handling

| | |
|---|---|
| **Commencement date:** | Ongoing |
| **Completion date:** | Life of MGIOMIP |

## 4.4 Promote awareness of *Darwinia masonii*

The status of *D. masonii* and measures to manage risk to the species will be promoted to staff at the MGIOMIP (while operational). The significance of the species will be communicated to personnel working at and around the mine site (i.e. environmental induction) by mining proponents.

Note that Parks and Wildlife will promote the awareness of the species to the wider community.

**Actions**:

- Promote need for protection through poster displays on the mine site (EHPL & MGM);
- Promote awareness to the wider community (Parks & Wildlife); and
- Promote awareness of *D. masonii* to mine site personnel through environmental inductions (EHPL & MGM).

**Responsibility**: MGM and EHPL; Parks & Wildlife

**Timing**: Ongoing for life of MGIOMIP

| | |
|---|---|
| **Commencement date:** | Ongoing |
| **Completion date:** | Life of MGIOMIP |

## 4.5 Implement *Darwinia masonii* condition monitoring program

MGM and EHPL will continue to implement a program for *D. masonii* condition monitoring.

The condition of *D. masonii* will be monitored for potential effects from dust, weeds, grazing and a drying climate. A minimum of 715 individual plants will be monitored annually between September and November. Parameters monitored for each plant will include: height (or length); reproductive status; infructescence production; life stage (seedling, juvenile, adult, dead); health; and herbivory. Newly recruited seedlings shall be tagged and monitored. These results will also be used to measure natural variability of population abundance.

Monthly inspections of plants in established quadrats will be continued, with plants assessed according to a plant health scale developed by BGPA. The monitoring results will be used to identify detectable effects, should they occur, not characteristic of natural seasonal variation, in a timely manner. Monitoring will continue for the life of mining at the site. Should monitoring not show any evident declining trend or step change in plant health, then the frequency of monitoring may, upon the advice of Parks & Wildlife, be set at quarterly intervals.

Dust deposition will be monitored using dust deposition gauges on a monthly basis to determine if there is any evidence of a correlation with dust generation in the event of a detrimental impact on *D. masonii* plants being identified.

Analysis of historical annual condition monitoring data has been conducted in 2014. Data has been collected in years from before the start as well as after commencement of mining in 2010. Detailed data analysis and interpretation of the outcomes of monitoring activities was conducted for MGM & EHPL by Astron Environmental Services (2014). Interpretation of the results from the data analysis were summarised as follows:

- There was strong temporal variation in survivorship, health condition and height between August 2007 and November 2013.
- In 2010 and 2013, poor health and lower survivorship were recorded. Survivorship at Mt Gibson South was lower than that of other monitoring sites. Death of up to 80% of individuals was recorded in some monitoring plots, and may be attributed to the age of the plants (i.e. natural attrition).
- Strong spatial variation in survivorship, health condition and height was not related to distance from the mine pit. The strong spatial variation was evident between monitoring sites (defined by location across the range) as well as between groups of monitoring sites (within a location; small-scale spatial variation).

Astron Environmental Services (2014) concluded that "*there was no evidence showing that health condition and survivorship of* D. masonii *was impacted by mining activity*".

Astron Environmental Services (2014) have made recommendations to improve the monitoring program, including:

- Establishing 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 2014, MGX engaged MBS Environmental (2015) to increase monitoring plots adjacent to the mine pit at Extension Hill. A total of 84 plants were monitored at distances between 30 and 60m from the edge of the pit. Dust deposition and evidence of fly rock from blasting activities were observed in monitoring plots close to the mine pit, however, there was no significant statistical difference in survivorship and plant health in comparison to plots at greater distances from the mine pit (MBS Environmental 2015).

Implementation of the above recommendations and a rolling analysis of plant condition monitoring data collected in the future will be undertaken to improve the *D. masonii* monitoring program. The results of the rolling analysis will be used to assess the effectiveness and improve recovery actions using an adaptive management approach.

**Actions**:

- Implement the condition monitoring program based on continual improvement (EHPL & MGM, 2015).
- Habitat health will be monitored annually in established plots using the plant condition criteria of Keighery (1994; EHPL & MGM, life of MGIOIP).
- Conduct dust deposition monitoring on a monthly basis using the dust deposition gauges around the mine (EHPL & MGM).
- Conduct annual monitoring of plants in 'fire' plots (EHPL & MGM).
- Report upon the condition monitoring program using a standardised reporting format on an annual basis (EHPL & MGM).
- Ascertain the role of drought in recruitment of *D. masonii* by analysis of annual condition monitoring data (EHPL & MGM, following drought periods during life of MGIOMIP).

**Responsibility**: MGM, EHPL

**Timing**: Annually (sometime during September – November each year) and monthly as described above

| | |
|---|---|
| **Commencement date:** | Ongoing |
| **Completion date:** | Life of MGIOMIP |

## 4.6 Implement Fire Management Strategy

Mt Gibson Range and the habitat of *D. masonii* are currently under a 'no controlled burn' fire management regime. Any fires occurring on the Mt Gibson Ranges are wildfires, or unplanned fires, which have the potential to occur as a result of mining activities.

MGM and EPHL are required to manage fire as a threatening process to *D. masonii* through the conditions that apply to the MGIOMIP under MS753.

**Actions**:

- Implement actions required to manage fire as a threatening process through the conditions that apply to the MGIOIP under MS753 (MGM and EHPL).
- Minimise the risk of fire occurring in the habitat of the populations, except where it is being used in regeneration trials (Parks and Wildlife).

**Responsibility**: MGM and EHPL; Parks and Wildlife

**Timing:** ongoing for life of mine

| | |
|---|---|
| **Commencement date:** | Ongoing |
| **Completion date:** | Life of MGIOMIP for mine-related actions, and otherwise life of the Recovery Plan |

## 4.7 Manage threatening processes from mining

MGM and EPHL are required to manage threatening processes from mining to *D. masonii* through conditions that apply to the MGIOMIP under MS753.

**Action**:

- Implement management actions required to manage threatening processes from mining through the conditions that apply to the MGIOMIP under MS753 and the Environmental Management Plan (EHPL & MGM, 2008).

**Responsibility**: MGM and EHPL

**Timing**: ongoing for life of mine

| | |
|---|---|
| **Commencement date:** | Ongoing |
| **Completion date:** | Life of MGIOMIP |

## 4.8 Protect plants from herbivory

Grazing has not been identified as having a significant effect on *D. masonii* (Section 1.3.7). The density of vertebrates grazing on the Mt Gibson Range may increase in the future (e.g. if the price of goats increases) and is usually determined by pastoral station managers. Non-native vertebrates, including rabbits and goats, are present within the Mt Gibson Ranges, and their impact on the vegetation varies between sites (BGPA, 2010). Grazing is a potential threat to the integrity of the areas of habitat of *D. masonii*. Grazing is also a potential threat to *D. masonii* if the distribution and density of preferentially grazed plants decline within the habitat, resulting in *D. masonii* becoming relatively more palatable to vertebrates.

The reporting from the annual condition monitoring program will continue to include an assessment of impacts of grazing on *D. masonii* and its habitat.

In the event that grazing pressure significantly affects *D. masonii*, either directly or through damage to associated habitat, the feral animal population will be controlled on the mining tenements through consideration of:

- Fencing (financial provision and logistic capability required); and
- Feral animal eradication (pastoral consent required).

**Action**:

- Continue to review grazing effects in annual *D. masonii* condition monitoring data (see Section 4.5); and
- If grazing is having significant adverse impacts on *D. masonii* or its habitat, MGM and EHPL will facilitate an appropriate feral animal control program in consultation with relevant stakeholders.

**Responsibility**: MGM and EHPL; Parks and Wildlife

**Timing:** Annually

| | |
|---|---|
| **Commencement date:** | Ongoing |
| **Completion date:** | Life of MGIOMIP |

## 4.9 Monitor populations

All populations of *D. masonii* will be monitored for the purpose of conducting a stocktake of the occurrence of *D. masonii* in the wild. This compares to plant condition monitoring, which focusses on a subset and monitors the condition in that subset (see Section 4.5). This is a comprehensive form of monitoring that will occur once every five years unless the results from the condition monitoring program indicate that the population or health of mature plants is estimated to be outside of the stable population range. The results of population monitoring will be used to assess the effectiveness of, and improve, the recovery actions.

**Action**:

- Monitor the entire population within one year and at a rate of every five years; otherwise, a rate of every three years if the populations or health of mature plants is estimated outside of the stable population range (taking variations resulting from fire and other effects into account). See Section 2.2 for definition of stable population numbers. The most recent census was in 2014.

**Responsibility**: MGM and EHPL

**Timing**: 2019

| | |
|---|---|
| **Commencement date:** | On adoption of the Recovery Plan |
| **Completion date:** | Life of Recovery Plan |

## 4.10 Report any new occurrences of *Darwinia masonii*

MGM and EHPL will report to Parks and Wildlife any new plants or populations of *D. masonii* that MGM and EHPL may find, in accordance with the Threatened and Priority Flora Report Form, to ensure Parks and Wildlife have accurate data on the species.

**Action**:

- Report opportunistic observation of any 'new' plant or population record to Parks and Wildlife.

**Responsibility**: MGM and EHPL

**Timing**: Ongoing

| | |
|---|---|
| **Commencement date:** | 2015 |
| **Completion date:** | Life of Recovery Plan |

## 4.11 Review conservation status of the species

For the purposes of recovery planning, changes to conservation status include significant changes and trends in the:

- number of individuals;
- number of populations;
- number of locations;
- habitat quality and extent;
- extent of occurrence;
- area of occurrence; and,
- threats.

For example, a successful translocation trial or future regional discovery of additional records that has natural recruitment would change the conservation status by increasing the areas and abundance, but may not necessarily result in the IUCN category being altered or the species delisted.

The IUCN category of the species is currently 'Vulnerable'. A review of the current status of the species and comparison with the status at the time of its 'Vulnerable' classification indicates that there have been insufficient significant changes to justify a change of its current status.

Whilst there are significantly more known individuals due to further population census and research, and additional sub population discoveries, the species is still geographically restricted.

**Actions:**

- Review the conservation status of the species every five years; or more frequently when there are indications of significant change to the conservation status of the species.

**Responsibility:** Parks and Wildlife

**Timing:** 2015, indications of significant change to conservation status

| | |
|---|---|
| **Commencement date:** | 2015 |
| **Completion date:** | Life of Recovery Plan |

## 4.12 Review this recovery plan.

MGM and EHPL shall review and revise this Recovery Plan as and when directed by the CEO, OEPA (condition 6-7 of MS753), or every five years, whichever comes first.

**Actions:**

- Review and revise this Recovery Plan.

**Responsibility:** MGM & EHPL

**Timing:** 2020

| | |
|---|---|
| **Commencement date:** | 2020 |
| **Completion date:** | Life of Recovery Plan |

# 5 Further research to benefit recovery

The EPBC Act requires that this Recovery Plan provide for the research necessary to stop the decline of, and support the recovery of *D. masonii* so that its chances of long term survival in nature are maximised.

MGM and EHPL are required under conditions 6-1 and 6-4 of MS753 respectively, to prepare and implement a *D. masonii* Research Plan. They are required to review and revise the Research Plan as and when directed by the CEO, OEPA (condition 6-7 of MS753), and to implement revisions of the *Darwinia masonii* Research Plan (condition 6-8).

BGPA (2010) identified the need for further research, which is listed here if it has not already been included in the recovery actions in Section 4:

- Mapping of soil or regolith data for the region is suggested to refine distribution models to improve understanding and predictions of the habitat and restoration requirements for *D. masonii*. However the conduct of a species census in 2014 gives greater confidence in the area of occupancy of the species and so the need for a predictive model of distribution is considerably reduced.
- Identify the seed-eating moth species and survey for its occurrence in co-occurring species and related *Darwinia* species.
- Annual collection of a sample of (>10) infructescences of *D. masonii* from each major population to assess rates of seed predation and seed fill.

- 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 including the White-fronted Honeyeater in *D. masonii* pollination.

**Actions:**

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

**Responsibility:** MGM & EHPL

**Timing:** 2015-2020.

| | |
|---|---|
| **Commencement date:** | Commencement of the Recovery Plan |
| **Completion date:** | Life of Recovery Plan |

# 6 Legislative and decision making controls and obligations

## 6.1 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.

## 6.2 Guide for decision makers

Preceding sections of this Plan provide details of current and possible future threats to *D. masonii,* and the risk of each of the threatening processes on the species. Any further development in the vicinity of existing or potential habitat for *D. masonii* will require assessment under established referral and/or environmental assessment mechanisms of State and Commonwealth governments.

Significant actions which may compromise the objective of this Plan could have a significant impact on the species.

Decision makers should refer to this Recovery Plan, specifically the threatening processes, the objective of the Plan, and associated recovery actions, in making determinations relating to development in the vicinity of existing or potential habitat for *D. masonii*.

# 7 Interest groups, social and economic impacts and benefits

## 7.1 Role and interest of Aboriginal groups

The Badimia people were the registered native title claimants in the area (Badimia People WC96/98), however, the Badimia claim was dismissed by the Federal Court of Australia in March 2015 and in May 2015 the Court made a determination that no native title exists in the area.

There are registered ethnographic and / or archaeological sites within the habitat of *D. masonii* which are of cultural significance.

MGM and EHPL has undertaken consultation through stakeholder meetings since commencement of the IRP in 2008 and including the period during the preparation of this Recovery Plan. MGM and EHPL will continue to consult the Badimia people about any issues they may raise in relation to the company's activities in this area. Input and involvement will be welcome from any Aboriginal groups that have an active interest in areas that *D. masonii* occurs.

The works of Tehnas (2010) should be referenced to obtain information of the existence and status of aboriginal heritage sites and regional ethnography.

## 7.2 Affected interests

The known populations of *D. masonii* occur across a variety of land tenures including pastoral leases, Crown Reserve (Reserve 17367), Unallocated Crown Land, mining leases and native title areas. Based on the current records and known area of occurrence of *D. masonii*, interests potentially affected by, or involved in the implementation of this plan include:

MGM, EHPL, Pindiddy Aboriginal Corporation (Ninghan Station), Australian Wildlife Conservancy (Mt Gibson Station) and the Badimia People. Interests of others may be potentially affected by this Plan. In most cases, no undue impediment or restriction on current land use is likely to arise because of this recovery plan. Landholders and land management agencies may be affected through statutory planning and approval processes outside this Plan when seeking to alter the landscape or undertake actions that may impact on *D. masonii*.

Parks & Wildlife will seek permission from relevant managers and/or those with entitlements to lands where *D. masonii* occurs or may occur before recovery actions are undertaken on any such land.

## 7.3 Social and economic impacts and benefits

The presence of MGM and EHPL in the region and their proactive approach to supporting the implementation of this plan will provide both economic impact and benefit to the recovery of *D. masonii*, as well as economic and social advantages from their mining activities on the Mt Gibson Range.

The known habitat for *D. masonii* comprises ironstone formations that are also prospective for iron ore and exist under live mining leases. This Plan provides guidance for decisions by State and Commonwealth

governments with respect to further development proposals in the vicinity of existing or potential habitat for *Darwinia masonii*.

# 8 Implementation and evaluation

This plan has been prepared to the requirements of the Minister for the Environment (WA) on advice of the Environmental Protection Authority and Parks and Wildlife.

MGM and EHPL will implement the Recovery Plan as required by condition 6-6 of MS753, specifically the assigned recovery actions.

Parks and Wildlife as funded through offset 4 under condition 16 of MS753 will assist with the implementation of the Recovery Plan.

Recovery actions associated with evaluation and review of this Plan are provided in Section 4 include:

- Conduct an annual review (Appendix 10.5) to assess effectiveness of the implementation of this Recovery Plan;
- Provide an annual report on the Plan's progress to Parks and Wildlife's Corporate Executive and funding bodies (Section 4.1).
- MGM and EHPL shall review and revise this Recovery Plan as and when directed by the CEO, OEPA (condition 6-7 of MS753), or after five years, whichever comes first (Section 4.12).

This plan will continue to apply from the date of adoption for a minimum of 10 years, or until replaced by a revised Recovery Plan.

The Commonwealth Department of the Environment may evaluate the plan.

The estimated cost of implementing this Recovery Plan is described in Table 9. However, this estimated figure does not include site operational costs associated with implementing recovery actions that reduce threats from mining activities or associated restoration of post-mining landforms, other government agencies and private land owners.

**Table 9 Summary of recovery actions over five years and indicative costs**

| Section | Action | Responsibility | 2015 Budget ($) | 2016 Budget ($) | 2017 Budget ($) | 2018 Budget ($) | 2019 Budget ($) |
|---|---|---|---|---|---|---|---|
| **4.1 Coordinate recovery actions and liaise with stakeholders** | | | | | | | |
| 4.1 | Coordinate relevant recovery actions, and liaise with stakeholders. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.1 | Coordinate relevant recovery actions, and liaise with stakeholders. | Parks & Wildlife | | | | | |
| 4.1 | Implement the relevant actions in the Recovery Plan. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.1 | Implement the relevant actions in the Recovery Plan. | Parks & Wildlife | | | | | |
| 4.1 | Provide an annual report on the Plan's progress to Parks and Wildlife's Corporate Executive and funding bodies. | Parks & Wildlife | | | | | |
| **4.2 Develop and implement restoration strategy** | | | | | | | |
| 4.2 | Prepare *Darwinia masonii* restoration strategy and program (inclusive of translocation, recruitment and rehabilitation). | MGM & EHPL | 10,000 | - | - | - | - |
| 4.2 | Commence implementation of Restoration Strategy | MGM & EHPL | 10,000 | 20,000 | 10,000 | 10,000 | 10,000 |
| 4.2 | For rehabilitated landforms, further assessment of patterns of BIF rock and BIF gravel substrate, and varying degrees of soil depth and rockiness and growing media will be made to support growth of *Darwinia masonii*. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | - | - |
| 4.2 | Monitor the survival and sustainable establishment of the plants remaining from the preliminary planting trial of *Darwinia masonii* at the disused drill pad on Iron Hill East. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.2 | Monitor the survival of the plants (if they remain) from the planting trial established on the BIF rock | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |

| Section | Action | Responsibility | 2015 Budget ($) | 2016 Budget ($) | 2017 Budget ($) | 2018 Budget ($) | 2019 Budget ($) |
|---|---|---|---|---|---|---|---|
| | and BIF soil substrates north of Extension Hill | | | | | | |
| 4.2 | Identify parameters for the long-term viability of re-established populations of *Darwinia masonii*. | MGM & EHPL | - | 10,000 | 10,000 | - | - |
| 4.2 | Monitor translocations and supplement them as necessary. | MGM & EHPL | | | 15,000 | 15,000 | 15,000 |
| 4.2 | Review and update Restoration Strategy in order to meet criteria for success. | MGM & EHPL | - | - | 10,000 | - | - |
| **4.3 Maintain and use seed/germplasm collections to ensure material with a broad genetic base is available for conservation** | | | | | | | |
| 4.3 | Develop a seed collection plan to identify representative species in the PEC, their composition and abundance required to meet objectives (to be determined) for collecting the seed in the first place. | MGM & EHPL | 5,000 | - | - | - | - |
| 4.3 | Collate and annually check records of retained seed stock in storage. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.3 | One-off viability test of retained seed stock in storage. | MGM & EHPL | 2,000 | - | - | - | - |
| 4.3 | Targeted seasonal collection of seeds from key Mt Gibson Ranges populations (late October to early November). | MGM & EHPL | 7,500 | 7,500 | 7,500 | - | - |
| 4.3 | Propagation of live *Darwinia masonii* plants from wild collection seed stock and cuttings for the purposes of translocation. | MGM & EHPL | 20,000 | 20,000 | 20,000 | - | - |
| 4.3 | Provision of nominated seed samples to the Threatened Flora Seed Centre and BGPA | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.3 | Review adequacy of *ex situ* collection to inform future actions | MGM & EHPL | - | - | - | $2,000 | - |
| 4.3 | Supplementation of seed in storage (upon identification of inadequate stock levels) | MGM & EHPL | - | - | - | - | $7,500 (if req'd) |

| Section | Action | Responsibility | 2015 Budget ($) | 2016 Budget ($) | 2017 Budget ($) | 2018 Budget ($) | 2019 Budget ($) |
|---|---|---|---|---|---|---|---|
| **4.4 Promote awareness of *Darwinia masonii*** | | | | | | | |
| 4.4 | Promote need for protection through poster displays on the mine site | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.4 | Promote awareness to the wider community | Parks & Wildlife | | | | | |
| 4.4 | Promote awareness of *Darwinia masonii* to mine site personnel through environmental inductions. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| **4.5 Implement *Darwinia masonii* condition monitoring program** | | | | | | | |
| 4.5 | Implement the condition monitoring program for *Darwinia masonii* based on continual improvement.<br><br>Habitat health will be monitored annually in established plots. | MGM & EHPL | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| 4.5 | Conduct dust deposition monitoring on a monthly basis using dust deposition gauges. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.5 | Conduct annual monitoring of plants in 'fire' plots. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.5 | Report upon the condition monitoring program using a standardised reporting format on an annual basis. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.5 | Ascertain the role of drought in recruitment of D.*masonii* | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| **4.6 Implement Fire Management Strategy** | | | | | | | |
| 4.6 | Implement actions required to manage fire as a threatening process through the conditions that apply to the MGIOIP under MS753. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.6 | Minimise the risk of fire occurring in the habitat of the populations, except where it is being used in regeneration trials. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |

| Section | Action | Responsibility | 2015 Budget ($) | 2016 Budget ($) | 2017 Budget ($) | 2018 Budget ($) | 2019 Budget ($) |
|---|---|---|---|---|---|---|---|
| **4.7 Manage threatening processes from mining** | | | | | | | |
| | Implement management actions required to manage threatening processes from mining through the conditions that apply to the MGIOMIP under MS753. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| **4.8 Protect plants from herbivory** | | | | | | | |
| 4.8 | Continue to review grazing effects in annual *Darwinia masonii* condition monitoring data. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| 4.8 | If grazing is having an adverse impact on populations of *Darwinia masonii* or its habitat, MGM and EHPL will facilitate an appropriate feral animal control program in consultation with relevant stakeholders. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| **4.9 Monitor populations** | | | | | | | |
| 4.9 | Monitor the entire population within one year and at a rate of every 5 years; otherwise at a rate of every 3 years. | MGM & EHPL | - | - | - | - | 110,000 |
| **4.10 Report any new occurrences of *Darwinia masonii*** | | | | | | | |
| 4.10 | Report opportunistic observation of any 'new' plant or population record to Parks and Wildlife. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |
| **4.11 Review conservation status of the species** | | | | | | | |
| 4.11 | Review the conservation status of the species every 5 years. | Parks & Wildlife | | | | | |
| **4.12 Review this recovery plan** | | | | | | | |
| 4.12 | Review and revise this Recovery Plan. | MGM & EHPL | - | - | - | - | 15,000 |
| **5.0 Further research to benefit recovery** | | | | | | | |
| 5.0 | Prioritise the listed tasks and implement according to resourcing and budget considerations over a five year period. | MGM & EHPL | - | 20,000 | 20,000 | 20,000 | - |

| Section | Action | Responsibility | 2015 Budget ($) | 2016 Budget ($) | 2017 Budget ($) | 2018 Budget ($) | 2019 Budget ($) |
|---|---|---|---|---|---|---|---|
| 5.0 | Review and revise the *Darwinia masonii* Research Plan. | MGM & EHPL | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets | Site operation budgets |

* Parks and Wildlife is funded through offset 4 of condition 16 of MS753 by the proponents. The funding value is $110,000 p.a. Two of four environmental objectives pertain to the *D. masonii* Recovery Plan and are: assist with the development and implementation of the Recovery Plan for *D. masonii*; and, coordinate the management of the threatening processes (recovery actions) in relation to *D. masonii*.

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**Table 10. Exact locations of populations of *Darwinia masonii*** (not for publication)

| Pop | Location | Vesting | Purpose | Mining Tenements | Manager | Latitude | Longitude |
|---|---|---|---|---|---|---|---|
| 1A | Unnamed, unvested Reserve 17367. "Iron Hill South". Furthest ridge W of summit of Mt Gibson. | RDL | COM | M59/338<br>M59/454<br>M59/609 | Department of Lands<br>Extension Hill Pty Ltd | -29.6032429 | 117.1756703 |
| 2 | UCL. "Extension Hill". | NON | UCL | M59/339 | Department of Lands<br>Extension Hill Pty Ltd | -29.5799896 | 117.1651914 |
| 3 | Lot 4280/Lease 3114-602. "Extension Hill North". Boundary of Mt Gibson and Ninghan Stations. Ca. 800m E along fenceline from Gt Northern Hwy opposite a landing ground and then 400m north up ridge. [Extinct] | PLB<br>NON | PAS<br>UCL | M59/339 | Ninghan Pastoral lessee and Department of Lands<br>Extension Hill Pty Ltd | -29.5733333 | 117.1572778 |
| 4 | UCL. "Extension Hill South". Between Iron Hill North and Extension Hill. | NON | UCL | M59/338<br>M59/339 | Department of Lands<br>Extension Hill Pty Ltd | -29.5855916 | 117.1672760 |
| 5A | Unnamed, unvested Reserve 17367. "Iron Hill East". Continues onto UCL to the north (pop 5B). | RDL | COM | M59/338<br>M59/454 | Department of Lands<br>Extension Hill Pty Ltd | -29.5987403 | 117.1806088 |
| 5B | UCL. "Iron Hill East". Continues onto Reserve 17367 to the south (pop 5A). | NON | UCL | M59/338 | Department of Lands<br>Extension Hill Pty Ltd | -29.5956782 | 117.1769584 |
| 6A | Unnamed, unvested Reserve 17367. "Mt Gibson". Extending north into UCL (pop 6B) and Lot 4282/Lease 398-616 (pop 6C).Between Mt Gibson and Mt Gibson South. | RDL | COM | M59/338<br>M59/454 | Department of Lands<br>Extension Hill Pty Ltd | -29.5985840 | 117.1963885 |

| Pop | Location | Vesting | Purpose | Mining Tenements | Manager | Latitude | Longitude |
|---|---|---|---|---|---|---|---|
| 6B | UCL. "Mt Gibson". Extending south into Reserve 17367 (pop 6A) and east into Lot 4282/Lease 398-616 (pop 6C). | NON | UCL | M59/338 | Department of Lands<br>Extension Hill Pty Ltd | -29.5935264 | 117.1862897 |
| 6C | Lot 4282/Lease 398-616. "Mt Gibson". Extending south into Reserve 17367 (pop 6A) and west into UCL (pop 6B). | PLB | PAS | M59/338 | Mt Gibson pastoral lessee<br>Extension Hill Pty Ltd | -29.5961174 | 117.1920878 |
| 7 | Unnamed, unvested Reserve 17367. "Mt Gibson South". On ridge ca 1.2-2.2km SE from summit of Mt Gibson. | RDL | COM | M59/454<br>M59/609<br>M59/550 | Department of Lands<br>Extension Hill Pty Ltd | -29.6036016 | 117.1999798 |
| 8 | Unnamed, unvested Reserve 17367. "Iron Hill North". Furthest ridge W from Mt Gibson summit, on middle part of the ridge. | RDL | COM | M59/338 | Department of Lands<br>Extension Hill Pty Ltd | -29.5980882 | 117.1697750 |
| 9 | UCL. "Iron Hill North". Furthest ridge W from Mt Gibson summit, northern most population of ridge. | NON | UCL | M59/338 | Department of Lands<br>Extension Hill Pty Ltd | -29.5932879 | 117.1689925 |
| 10 | UCL. Extension Hill-East. East of Extension Hill on top of BIF breakaway above rock shelter and at the base of a valley on BIF substrate. | NON | UCL | M59/339 | Department of Lands<br>Extension Hill Pty Ltd | -29.5816667 | 117.1690000 |

# 10 Appendices

## Appendix 10.1 How This Recovery Plan Meets The Requirements of MS753

Ministerial Statement 753 (MS753) authorises the implementation of the Mount Gibson Iron Ore Mine and Infrastructure Project (MGIOIP), being the proposal to mine and produce iron ore from Extension Hill and Extension Hill North, within the Mount Gibson Ranges, construct a pipeline to transport the magnetite concentrate to Geraldton Port, and construct infrastructure at the port to dewater the concentrate for export.

Mount Gibson Mining Ltd (MGM) and Extension Hill Pty Ltd (EHPL) are both proponents for the purposes of MS753.

This Recovery Plan (Plan) has been prepared to meet condition 6-3 of Ministerial Statement 753 (MS753), which authorises the implementation of the Mount Gibson Iron Ore Mine and Infrastructure Project (MGIOIP) (Table 11). It has been informed by the findings of the *Darwinia masonii* Research Plan and the *D. masonii* IRP which were developed and implemented pursuant to conditions 6-1, 6-2, 6-4 and 6-5 of MS753. A summary of the outcomes of the Research and IRP is provided by way of background in sections 1.1, 1.2 and 3 of this plan.

**Table 11. Aspects of the Plan which address the matters stipulated by Condition 6-3 of MS753**

| MS753 Condition | Matters | Section |
|---|---|---|
| 6-3(1) | *Habitats which are critical to the survival of the species*<br>*Actions needed to protect those habitats* | Section 1.2; Table 1; Figure 4.<br>Section 4 |
| 6-3(2) | *Threats to the species and areas and populations under threat* | Section 1.3 |
| 6-3(3) | *Objectives to be achieved* | Section 2.1 |
| 6-3(4) | *Criteria against which achievement of the objectives is to be measured* | Section 2.2 |
| 6-3(5) | *Management actions based on the outcomes of the implementation of the Research Plan and Interim Recovery Plan that will remediate the impacts of the project and provide for a net improvement on the pre-mining status of the species* | Section 4 |
| 6-3(6) | *Further research required into the management or recovery of the species* | Section 5 |

The objective of this Plan is to abate identified threats and maintain or enhance *in situ* populations to ensure the long-term conservation of *D. masonii* in the wild (see Section 2.1). This objective meets condition 6-3 of

MS753, which required the preparation of a recovery plan "*to maintain, and ultimately improve, the conservation status of D. masonii such that its conservation status is more secure in the Mt Gibson area"*.

MS753 includes several conditions which regulate the implementation of the MGIOIP in a manner that will manage the effects of the MGIOIP on *D. masonii* e.g., condition 8 (conservation of significant flora and communities), condition 9 (weeds) and condition 10 (bushfires). This Plan is intended to work alongside those obligations (and particularly the management plans that operate under those conditions) to meet the Plan objectives and maintain an efficient process. Where conditions are directly related to the management or recovery of *D. masonii* they have been referenced in the relevant Recovery Actions in this Plan (Section 4).

## Appendix 10.2 Legislative Requirements

The Recovery Plan has been developed using the structure and addresses the matters outlined in the "Recovery Plan Guidelines for Nationally Listed Threatened Species and Ecological Communities" under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (Recovery Plan Guidelines). Table 122 is a condensed version of the Department of the Environment's compliance checklist:

**Table 12. Aspects of the Plan which address the Recovery Plan Guidelines under the *EPBC Act* 1999.**

| | **Requirements of the Recovery Plan Guidelines** | **Section of this Plan** |
|---|---|---|
| 1 | Consultation with relevant departments | Consultation with relevant government departments and Decision Making Authorities has been on-going since MGIOIP was Referred under the EPBC and EP Acts. Since that time, on-going consultation has occurred in the development and implementation of the IRP, through the funding of a Parks and Wildlife officer position, and through the development of this Recovery Plan. |
| 2 | Consultation with other stakeholders | Consultation with scientists and specialists has also occurred during the MGIOIP development, approvals and operations with regard to *D. masonii*. Refer to the Foreword and Section 7 of this Plan. |
| 3 | Public consultation | The Public Environmental Review document was made available for public comment and the IRP is publically available. |
| 4 | Objects of the Act | Objects a-c: the *Darwinia masonii* Recovery Plan<br>Object d: Consultation (as above (1-3))<br>Object e: International responsibilities (Section 6.1)<br>Objects f & g: The role and interests of indigenous people (Section 7.1) |
| 5 | International agreements | Section 6.1 |
| 6 | Indigenous People | Section 7.1 |
| 7 | Social and economic impacts | Section 7.3 |
| 8 | Efficient and effective use of resources | Section 8 |
| 9 | Species listed as threatened (EPBC Act) | *Darwinia masonii* is listed as Vulnerable under the EPBC Act. |
| 10 | Taxonomic or common names used | The taxonomic name, *Darwinia masonii*, is used throughout the document. |
| 11 | Distribution of the species | Section 1.1.4 and Table 10. Exact locations of populations of *Darwinia masonii* (not for publication) |
| 12 | Population(s) | Section 1.2 |

| | Requirements of the Recovery Plan Guidelines | Section of this Plan |
|---|---|---|
| 13 | Define habitat critical to survival | Section 1.2 |
| 14 | Description of habitat - spatial | Section 1.2 |
| 15 | Threats | Section 1.3 |
| 16 | Areas affected by threats | Section 1.3 |
| 17 | Population(s) under pressure of survival | Section 1.3 |
| 18 | Recovery objectives | Section 2.1 |
| 19 | Measurable criteria | Section 2.2 |
| 20 | Evaluation of performance | Section 8 |
| 21 | On-ground actions | Section 4 |
| 22 | Cost | Section 8 |
| 23 | Management practices | Section 4 |
| 24 | Biodiversity benefits/impacts | Section 1.4 |
| 25 | Affected interests | Attachment 7.2 |
| 26 | Social and economic benefits/impacts | Attachment 7.3 |

## Appendix 10.3 Biology and Ecology of Darwinia *masonii*

**Illustrations and/or further information**

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**Biology and Ecology**

*Darwinia masonii* 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 naturally limited as a result of limiting natural factors such as edaphic requirements and/or breeding biology. *Darwinia masonii* represents a highly specialised case of a nationally significant, intrinsically rare species.

**Population Demography**

BGPA (2010) studied the demography of *Darwinia masonii* populations on Extension Hill South, Iron Hill South, Mt Gibson Hill and Mt Gibson Hill South between 2007 and 2010 (2010). Tagged plants were monitored in fifteen 10 by 10m plots, with 5 plots each within vegetation characterised by 3 fire histories (2003; 1969; or, older – pre-1968). Four additional plots with total area of 250m$^2$ were added in May 2009 within the boundary of an experimental fire at the northern end of Extension Hill South. Parameters measured in the plots included: location of plant within the plot; plant structure (seedling, adult); height (or length for reclining or prostrate plants); canopy diameter in 2 perpendicular dimensions; stem basal diameter in 2 perpendicular dimensions; inflorescence numbers; and, 'health'.

Growth

Mature plants of *Darwinia masonii* have a slow, irregular and modular growth form (BGPA, 2010). Seedling growth forms are more regular with increases in height correlated with age. Older plants may experience dying back of branchlets at their extremities during drought years, and branchlet growth within the canopy during good seasons. The growth rate of *D. masonii* seedlings in plots burnt in 2003 averaged 3.4cm/yr, while the rate of mature and old plants was neutral or negative with an average of -0.9cm/yr during the period between 2007

and 2009 (BGPA, 2010). The average growth rate also varied for each year in this range, demonstrating that the plant growth responded to the annual growing conditions.

The growth patterns of *Darwinia masonii* change once the plants become reproductive, and can be used to explain differences in growth rate. Seedlings have a vertical growth direction, and the growing tip persists from year to year. BGPA (2010) found that this pattern of growth persisted until the plants were between 50 and 70cm tall. Once *Darwinia masonii* 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. Their height (or length for reclining or prostrate plants) varies from year to year dependant on the growth conditions experienced.

Seedling growth forms of *Darwinia masonii* display a correlation between stem diameter and growth patterns (BGPA, 2010). In contrast, stem diameter of mature and old plants was found to be unsatisfactory as an assessment measure of growth rate on an annual basis. The stems of seedlings are regular in shape, and the change in stem diameter of *Darwinia masonii* seedlings in plots burnt in 2003 averaged 0.34mm/yr during the period between 2007 and 2009. This varied for each year within this range, indicating that stem diameter responded to annual growing conditions. The stems of mature and old plants are often irregularly shaped, having cracks, swellings, or a presence or absence of spongy bark. Furthermore, the bark can swell, shrink or be sloughed off. These are all characteristics which elucidate why stem diameter is an unsatisfactory parameter for measuring growth of mature and older individuals of *Darwinia masonii*.

Fecundity

Plants have been recorded flowering between April and November (Brown *et al*., 1998). In 2009, BGPA (2010) recorded flowers opening between late August and late October.

Flowering of *Darwinia masonii* has been recorded in plants as young as six years (BGPA, 2010). Six of 115 plants recorded in plots burnt in 2003 at Iron Hill South were recorded to be flowering for the first time in 2009. These plants were in the tallest height category (51 to 95cm), but only represented 13% of the individuals within that category.

Tall (old) individuals of *Darwinia masonii* that have a wide canopy are more likely to produce flowers, and in greater numbers, than smaller (young) individuals with narrow canopy diameter (BGPA, 2010). The proportion of plants recorded to be flowering during the period between 2007 and 2009 increased with plant height (or length, for reclining or prostrate individuals). This proportion was comparable for all plants with a canopy diameter of over 1 metre wide. However, the number of flowers per plant was proportional to canopy diameter.

The percentage of plants flowering and the number of inflorescences varied for each year within the period between 2007 and 2009 (BGPA, 2010), but the reason for this has not been determined. 62% of all plants in older sites (burnt during or before 1969) flowered in 2007, while this dropped to 36% in 2008, and increased once more to 90% in 2009. The number of flowers per plant displayed the same pattern.

Population structure

*Darwinia masonii* is long-lived and killed by fire (Armstrong and Associates, 2004; BGPA, 2010; Section 1.1.5). A wildfire burnt out a significant area in southern and eastern portions of the Ranges in January 2003. None of the *D. masonii* plants burnt during this fire were observed to have survived during the spring of 2003 by

Armstrong and Associates (2004). Regeneration is restricted exclusively to germination from seed held in long-lived soil-stored seedbanks (BGPA, 2010). Plants arising from seed germinate in a single cohort post-fire. There is also evidence of limited post-fire recruitment of *D. masonii* in older populations. Plant sizes from data collected in 2007 during BGPA's (2010) demographic study ranged in height up to 240 cm and 2.5m in canopy width. The largest stem diameter was 74mm. Plant size correlated with population age in frequency distribution graphs of the young (2003) and mature (1969) plots which showed distinct peaks in size and a narrow size range. The older (pre-1968) plots were estimated to have been unburnt for over 85 years and had the oldest and largest plants in them. However, the frequency distribution graphs did not have distinct peaks in size, but rather a spread of plant sizes. The data from the older plots confirmed that *D. masonii* is long-lived and that limited recruitment occurs at infrequent intervals in the absence of fire.

Recruitment

Recruitment in the plots within the boundary of the experimental fire of May 2009 confirmed that *D. masonii* germinates strongly after fire, with a seedling density in burnt areas of 1.2/$m^2$ and 3.2 seedlings per pre-fire adult (BGPA, 2010). The fire on 12 May 2009 was not as intense as anticipated and was patchy, such that 73 of the 93 pre-fire adults were burnt. However, it achieved what was intended: it killed the canopy; there was a good amount of ash produced; and, seedlings emerged. Soil temperature at some of the probe sites did reach 250$^{o}$C (B Miller 2013, pers. comm., 17 December). 233 seedlings were counted within the area burnt in the experimental fire plots, in comparison recruitment of only one seedling in the 15 unburnt plots over the course of the study (May 2007 to June 2010). This seedling was recorded in an older (pre-1968) plot on Mt Gibson South in July 2009. This corroborates the findings of the population structure study - that post-fire recruitment is limited in older populations but does occur.

Survival/Mortality

BGPA (2010) reported that, "While mortality is rare among mature *D. masonii* plants, drought over the winter of 2010 contributed to a significant level of mortality (>10% in one site)" (p6). Two plants out of 249 recorded in the older (pre-1968) plots died between 2007 and 2009. This equates to an average of 0.5% deaths per year. The rainfall total over 2010 was one of the lowest on record, and mortality in a sample of 261 plants resurveyed at Mt Gibson South during BGPA's pollination study was 10.3%. The magnitude of the mortality after this single drought year is of concern, as it indicates that populations of *D. masonii* could be significantly impacted by drought, and there may be implications for the taxon if climate change results in increased drying or a greater frequency of dry years in the region.

There is significant spatial and temporal variation in mortality of *D. masonii* seedlings (BGPA, 2010). Between 2007 and 2009, 33 seedlings died out of the 128 seedlings recorded in 5 plots which were last burnt at Iron Hill South in 2003. The death rate for these plots varied each year, ranging from 2.5% to 15% per year. It also varied between the plots at Iron Hill South. BGPA (2010) suggest possible reasons for the variation in seedling mortality, including seasonal variation in rainfall, soil water holding capacity and microclimate of the plots.

It is also possible that seedlings of *Darwinia masonii* are less resilient to drought conditions than mature plants. Of the seedlings tagged in the recruitment plots within the boundary of the experimental fire of May 2009, only 9% were still alive when these plots were revisited in October 2010. BGPA (2010) stated "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" (p43).

**Pollination**

Flowers of *Darwinia masonii* exhibit pollen presentation, with the pollen exuding from the anthers and being deposited within an oily pollenkitt on a band of hairs just below the tip of the style before the flower opens (anthesis) (BGPA, 2010). Pollen presentation is efficient at depositing pollen in a single area on a pollinator's body, but also may increase the likelihood of self-pollination.

*Darwinia masonii* is capable of producing low-viability, self-pollinated (selfed) seeds but the production of outcrossed seed is a critical requirement for self-sustaining populations, as there was weak evidence that selfed seed was less fit than outcrossed seed BGPA (2010). BGPA (2010) reported that *D. masonii* is able to self-pollinate at a low rate (6.6%) in the absence of pollinators, however full access to pollinator activity significantly increased seed set (to 23%). The study was not powerful enough to unambiguously separate the actions of pollinator classes (birds versus insects), however the trend agrees well with pollinator observations: rare insect visitation increases the outcrossing rate (and seed set), however birds are much more effective pollinators and more common visitors, resulting in a higher seed set.

*Darwinia masonii* is known to be pollinated by the White-fronted Honeyeater (*Phylidonyris albifrons*) (BGPA, 2010).

**Seed production and seed biology**

*Darwinia masonii* seed production takes place in spring and early summer with the peak of ripe seed production occurring around mid-November in 2009 (BGPA, 2010). The peak period for seed collection depends on the relative rates of seed development and seed drop and may vary between years and localities. Seed fill rates varied between years from 15 to 30%. Seed dispersal occurs by ants. *Darwinia masonii* seed production is moderately low, varying between years from 9 to 59 seeds per plant in mature populations. Inbreeding and predation by moth larvae contribute to reduced seed quality. Seed predation rates varied between years from 6 to 22%.

**Seed germination and dormancy**

BGPA (2010) stated that large scale production of seedlings of *Darwinia masonii* via germination of fresh or stored seed involves physical manipulation of small seeds for seed coat nicking or removal, or retrieval of seed buried for months or years. They reported that:

- *Darwinia masonii* seed has a physical and physiological dormancy process (removal/breakdown of fruit walls and stimulatory effect of smoke chemicals, respectively). The germination rate of fresh *Darwinia masonii* seed was low but was improved by a combination of detailed physical treatments and smoke application.
- Preliminary results of *in situ* seed burial trials indicated complex germination / dormancy strategies for *D. masonii*, 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. Germination rates of 90% were achieved with filled seed exhumed after 9 months of burial and treated with smoke water.

The seed buried for seed bank demography trials established for *D. masonii* is still in place. These experiments were designed to continue for up to 5 years.

**Environmental adaptations**

*Darwinia masonii* shares with co-occurring species the drought avoiding strategy of closing down transpiration and photosynthetic function to enter a period of physiological dormancy through drought with the capacity to restore tissues as soils wet.

Roots of *D. masonii* have a capacity to enter large cracks, pores and fissures in regolith and may achieve considerable root depths (perhaps to >10m), but the species did not show root growth adaptations that were significantly different from close relatives from other habitats.

**Biotic interactions**

Pollination, seed predation and seed dispersal has already been discussed in this section.

The IRP (DEC, 2008) stated that "only very minor grazing pressure from feral goats and rabbits of D. masonii has been observed to date" (p10). However, BGPA (2010) found that grazing by vertebrates (presumed to be goats and rabbits) had a negligible impact on *D. masonii*. They conducted monitoring of over 350 seedlings and adult plants between 2007 and 2010 in demography plots, and in excess of 200 seedlings in plots established in an area subjected to an experimental burn. No evidence of mammalian herbivory was observed on any plant (seedling or adult) monitored. Branch tip pruning of 4 tagged plants was observed in 2007 and was presumed to have been caused by parrots eating flowers or seeds.

*Darwinia masonii* has a clear association with Vesicular-Arbuscular Mycorrhizae (VAM) (BGPA, 2010). No obvious Ectomycorrhizal (ECM) formation was recorded in field-collected root systems of the plant. BGPA (2010) suggested that comparative restoration trials be used to further investigate the importance of mycorrhizal formation to the restoration success of *D. masonii*.

Competition or facilitation was not observed by BGPA (2010), but they suggested that future restoration research include manipulative experiments under field conditions to best determine the extent of these interactions.

The impact of termites on *D. masonii* has not appeared to be significant. Proportionally, they have been recorded on a small number of plants – they were observed on the stems of 15 tagged individuals in demography plots burnt during or before 1969 (BGPA, 2010). The mean growth rates and health scores of these individuals did not vary greatly from other termite-free individuals in the same areas.

Foliar loss or damage by insect attack was only noted in the form of galls on a very small number of D. masonii individuals during BGPA's (2010) research.

Wood rots are likely to have a very minor impact on *D. masonii* (BGPA, 2010). No evidence of fungal rotting was recorded on wood of dead or burnt plants which had persisted for many years after death. An unidentified fruiting bracket fungus was found on the trunks of live plants during BGPA's research.

**Abiotic associations**

BGPA (2010) used two approaches to determine the environmental associations of *D. masonii*: an analysis of site factors at demographic and physiological monitoring plots; and, modelling of species distributions against spatially mapped environmental data. The environmental parameters interrogated by the modelling were

geology, short term fire history (since 1968), solar radiation receipt, aspect, slope, curvature and elevation. Of these, slopes over 7-8°, elevation over 380m and all geology types within the Mt Gibson Ranges except "White Rock (unclassified, including granite and its group, acidic dyke rocks, feldspar porphyry and meta-sediments phyllitic rock)" were the principal environmental parameters predicting the distribution of *D. masonii*. When each of these was considered alone they had an associated probability of 50 to 60% of predicting the *D. masonii* distribution.

The modelling predicted *D. masonii* to occur broadly across the Mt Gibson ranges with a high probability (60-75%) of occurrence (BGPA, 2010). It is interesting to note that the modelling also predicted suitable habitat for *D. masonii* on Yandanhoo Hill to the east of the Mt Gibson Ranges. Many areas in the Mt Gibson Ranges where populations were most highly predicted to occur by the modelling do not support *D. masonii*. BGPA concluded that the distribution of *D. masonii* may have an association with unmapped sub-surface features such as regolith (soil depth, underlying rock structure) and longer-term fire history patterns. They postulated that some areas of the Mt Gibson range are more prone to fire than others.

*In situ* planting methods using cuttings were trialled by BGPA (2010) at Mt Gibson on 4 differing field soil substrates. These were on the deep red loam/clay plains east of Extension Hill (clay), white-yellow sands of sandplains west of Extension Hill (sand), and gravelly and rocky loams of the north Extension Hill slope and ridge (BIF gravel and BIF rock respectively). *Darwinia masonii* survival after 9 months of planting was only successful in sites with BIF rock and BIF gravel substrate. The highest survival was at the BIF rocky loam site which averaged under 40%. Both sites had significantly higher Organic Carbon (%) and Total Nitrogen (%) than the clay and sand sites. The BIF rock and BIF gravel sites had slower soil drying curves than the sand and clay sites. *Darwinia masonii* is not currently known from sandy or clayey sites like those selected for the restoration trial, and perhaps the factors contributing to the lack of success of the cuttings planted provides some explanation for this. Conversely, BGPA (2010) concluded that sites with BIF rock and BIF gravel are suitable for translocations, and texture, gravel/rock content, patterns of moisture content and Total Nitrogen may be the most critical soil properties to consider in site selection. These properties may also contribute more broadly in defining the current and potential habitat of *D. masonii*.

## Appendix 10.4 Risk Assessment Criteria

The *Darwinia masonii* risk assessment was based on the framework of the Australian and international standard for risk management AS/NZS ISO 31000 (2009).

Risk assessment is the basis of management and mitigation measures applied through the approved "Extension Hill & Extension Hill North Environmental Management Plan", prepared to meet the conditions of Ministerial Statement No. 753 (in particular conditions 6 to 12 and 14 of Ministerial Statement No. 753).

The main elements of the risk assessment process required:

- identification of the potential threats, cause of the threat and potential impact on the species (Table 3; termed 'Inherent Risk'); and
- estimating the likelihood of each threat occurring, the potential environmental consequences if it did occur and the subsequent determination of an inherent risk rating in context of the current controls (Table 3; termed 'Controlled Risk');
- consideration of recovery actions to further mitigate risk; and
- re-estimating the likelihood of each risk event occurring and the potential environmental consequences if it did occur, and the subsequent determination of a residual risk rating (Table 3; termed 'Residual Risk').

## Risk Assessment Matrix

| RISK MATRIX | | Likelihood | | | | |
|---|---|---|---|---|---|---|
| | | A<br>Certain | B<br>Probable | C<br>Possible | D<br>Remote | E<br>Improbable |
| **Rating** | **Consequence** | **(Common)**<br>*It is expected to occur in most circumstances.*<br>*Guide (> 90%)* | **(Likely)**<br>*Will probably occur in most circumstances.*<br>*Guide (51-90%)* | **(Could Happen)**<br>*Should occur at some time.*<br>*Guide (21-50%)* | **(Not Likely)**<br>*Could occur at some time.*<br>*Guide (10-20%)* | **(Rare)**<br>*May occur only in exceptional circumstances.*<br>*Guide (<10%)* |
| **1**<br>**Catastrophic** | Severe reduction in population between 71-100% of known records.<br>Intergenerational timeframe for restoration if at all. High cost, long term involvement. | **1** | **2** | **5** | **7** | **11** |
| **2**<br>**Major** | Reduction of 31-70% of known records<br>Long term restoration, high cost and involvement 21 – 100 years. | **3** | **4** | **8** | **12** | **16** |
| **3**<br>**Moderate** | Reduction of between 11-30% of known records<br>Medium reversibility estimate 6 - 20 year recovery timeframe. | **6** | **9** | **13** | **17** | **20** |
| **4**<br>**Minor** | Reduction of 1-10 % of known records<br>Should be reversible within 6 year timeframe. | **10** | **14** | **18** | **21** | **23** |
| **5**<br>**Insignificant** | No discernable effect | **15** | **19** | **22** | **24** | **25** |

* Environment descriptors have been modified to align with description of severity from WWF 2007

## Appendix 10.5 Annual Review Checklist

All parties responsible for implementing actions in this plan shall be audited to determine the effectiveness of assigned actions and inform future revisions of this Recovery Plan. An audit checklist (Table 13) clearly identifies the specific future actions (as listed in the Recovery Plan) required to address the recovery of *D. masonii* on the Mt Gibson Range, the party responsible for implementation, the timing for implementation and a suitable audit mechanism by which the action may be assessed (although further evidence may be requested by the audit team).

**Table 13 Review Checklist**

| Section | Action | Responsibility | Timing | Reporting mechanism |
|---|---|---|---|---|
| **4.1 Coordinate recovery actions and liaise with stakeholders** | | | | |
| 4.1 | Coordinate relevant recovery actions, and liaise with stakeholders. | MGM & EHPL | On-going | Stakeholder register and records |
| 4.1 | Coordinate relevant recovery actions, and liaise with stakeholders. | Parks & Wildlife | On-going | Annual progress report |
| 4.1 | Implement the relevant actions in the Recovery Plan. | MGM & EHPL | On-going | Annual Environmental Report |
| 4.1 | Implement the relevant actions in the Recovery Plan. | Parks & Wildlife | On-going | Annual progress report |
| 4.1 | Provide an annual report on the Plan's progress to Parks and Wildlife's Corporate Executive and funding bodies. | Parks & Wildlife | Annually | Annual progress report |
| **4.2 Develop and implement restoration strategy** | | | | |
| 4.2 | Prepare Darwinia masonii restoration strategy and program (inclusive of translocation, recruitment and rehabilitation). | MGM & EHPL | 2014 | Restoration strategy |
| 4.2 | Commence implementation of Restoration Strategy | MGM & EHPL | 2015 | Annual Environmental Report |

| Section | Action | Responsibility | Timing | Reporting mechanism |
|---|---|---|---|---|
| 4.2 | For rehabilitated landforms, further assessment of patterns of BIF rock and BIF gravel substrate, and varying degrees of soil depth and rockiness and growing media will be made to support growth of *Darwinia masonii*. | MGM & EHPL | 2015-2017 | Annual Environmental Report |
| 4.2 | Monitor the survival and sustainable establishment of the plants remaining from the preliminary planting trial of *Darwinia masonii* at the disused drill pad on Iron Hill East. | MGM & EHPL | 2014-2017 | Annual Environmental Report |
| 4.2 | Monitor the survival of the plants (if they remain) from the planting trial established on the BIF rock and BIF soil substrates north of Extension Hill | MGM & EHPL | 2014-2017 | Annual Environmental Report |
| 4.2 | Identify parameters for the long-term viability of re-established populations of *Darwinia masonii*. | MGM | On-going | Restoration strategy |
| 4.2 | Monitor translocations and supplement them as necessary. | MGM | 2016-2019 | Annual Environmental Report |
| 4.2 | Review and update Restoration Strategy in order to meet criteria for success. | MGM | Annually | Restoration strategy (revision # and date) |
| **4.3 Maintain and use seed/germplasm collections to ensure material with a broad genetic base is available for conservation** | | | | |
| 4.3 | Develop a seed collection plan to identify representative species in the PEC, their composition and abundance required to meet objectives (to be determined) for collecting the seed in the first place. | MGM & EHPL | 2014 | Seed collection plan |
| 4.3 | Collate and annually check records of retained seed stock in storage. | MGM & EHPL | Annually | Spreadsheet of seed records |
| 4.3 | One-off viability test of retained seed stock in storage. | MGM & EHPL | 2015 | Annual Environmental Report |

| Section | Action | Responsibility | Timing | Reporting mechanism |
|---|---|---|---|---|
| 4.3 | Targeted seasonal collection of seeds from key Mt Gibson Ranges populations (late October to early November). | MGM & EHPL | 2015-2016 | Spreadsheet of seed records |
| 4.3 | Propagation of live *Darwinia masonii* plants from wild collection seed stock and cuttings for the purposes of translocation. | MGM & EHPL | 2015 - 2017 | Annual Environmental Report |
| 4.3 | Provision of nominated seed samples to the Threatened Flora Seed Centre and BGPA | MGM & EHPL | 2014-2017 | Annual Environmental Report |
| 4.3 | Review adequacy of *ex situ* collection to inform future actions | MGM & EHPL | 2017 | Annual Environmental Report |
| 4.3 | Supplementation of seed in storage (upon identification of inadequate stock levels) | MGM & EHPL | 2018 - 2019 | Annual Environmental Report |
| **4.4 Promote awareness of *Darwinia masonii*** | | | | |
| 4.4 | Promote need for protection through poster displays on the mine site | MGM & EHPL | On-going | Posters |
| 4.4 | Promote awareness to the wider community | Parks & Wildlife | On-going | Annual Progress Report |
| 4.4 | Promote awareness of *Darwinia masonii* to mine site personnel through environmental inductions. | MGM & EHPL | On-going | Induction materials |
| **4.5 Implement *Darwinia masonii* condition monitoring program** | | | | |
| 4.5 | Implement the condition monitoring program for Darwinia masonii based on continual improvement.<br><br>Habitat health will be monitored annually in established plots. | MGM & EHPL | Monthly; Annually | Technical Report |
| 4.5 | Conduct dust deposition monitoring on a monthly basis using dust deposition gauges | MGM & EHPL | Monthly | Annual Environmental Report |

| Section | Action | Responsibility | Timing | Reporting mechanism |
|---|---|---|---|---|
| 4.5 | Conduct annual monitoring of plants in 'fire' plots. | MGM & EHPL | Annually | Annual Environmental Report |
| 4.5 | Report upon the condition monitoring program using a standardised reporting format on an annual basis. | MGM & EHPL | Annually | Annual Environmental Report |
| 4.5 | Ascertain the role of drought in recruitment of D.masonii | MGM & EHPL | Annually | Annual Environmental Report |
| **4.6 Implement Fire Management Strategy** | | | | |
| 4.6 | Implement actions required to manage fire as a threatening process through the conditions that apply to the MGIOIP under MS753. | MGM & EHPL | On-going | Annual Environmental Report |
| 4.6 | Minimise the risk of fire occurring in the habitat of the populations, except where it is being used in regeneration trials | MGM & EHPL | On-going | Annual Environmental Report |
| **4.7 Manage threatening processes from mining** | | | | |
| | Implement management actions required to manage threatening processes from mining through the conditions that apply to the MGIOIP under MS753. | MGM & EHPL | On-going | Annual Environmental Report |
| **4.8 Protect plants from herbivory** | | | | |
| 4.8 | Continue to review grazing effects in annual Darwinia masonii condition monitoring data. | MGM & EHPL | Monthly; Annually | Annual Environmental Report |
| 4.8 | If grazing is having an adverse impact on populations of *Darwinia masonii* or its habitat, MGM and EHPL will facilitate an appropriate feral animal control program in consultation with stakeholders. | MGM & EHPL | As required | Stakeholder consultation register;<br><br>Annual Environmental Report |
| **4.9 Monitor populations** | | | | |

| Section | Action | Responsibility | Timing | Reporting mechanism |
|---|---|---|---|---|
| 4.9 | Monitor the entire population within one year and at a rate of every 5 years; otherwise at a rate of every 3 years. | MGM & EHPL | As required | Annual Environmental Report |
| **4.10 Report any new occurrences of *Darwinia masonii*** | | | | |
| 4.10 | Report opportunistic observation of any 'new' plant or population record to Parks and Wildlife. | MGM & EHPL | On-going | Threatened and Priority Flora Report Form |
| **4.11 Review conservation status of the species** | | | | |
| 4.11 | Review the conservation status of the species every 5 years. | Parks & Wildlife | 2015 | Annual Progress Report |
| **4.12 Review this recovery plan** | | | | |
| 4.12 | Review and revise this Recovery Plan. | MGM & EHPL | 2020 or as required. | Revision number and date of this Recovery Plan |
| **5.0 Further research to benefit recovery** | | | | |
| 5.0 | Prioritise the listed tasks and implement according to resourcing and budget considerations over a five year period. | MGM & EHPL | 2015 | Annual Environmental Report |
| 5.0 | Review and revise the *Darwinia masonii* Research Plan. | MGM & EHPL | 2016 - 2018 | Annual Environmental Report |

# Appendix 2 *Darwinia masonii* Conservation and Restoration Research Report

# *Darwinia masonii* and *Lepidosperma gibsonii*

## Conservation and Restoration Research

An integrated research program into the *ex situ* and *in situ* conservation, restoration and translocation requirements of *Darwinia masonii* and *Lepidosperma gibsonii* May 2007- June 2010

Report to Sponsors
October 2010

**Botanic Gardens and Parks Authority (Kings Park and Botanic Garden)**
**("BGPA")**

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## Table of Contents


**1 INTRODUCTION ..... 3**
**2 EXECUTIVE SUMMARY ..... 5**
**3 PROJECT BACKGROUND ..... 13**
3.1 RELATED DOCUMENTS ..... 14
3.2 OTHER RESEARCH ..... 15
**4 FINDINGS ..... 17**
4.1 CONSERVATION GENETICS ..... 17
4.1a Phylogenetic context ..... 17
4.1b Landscape scale genetic structure ..... 20
4.1c Monitoring genetic threats ..... 33
4.2 POPULATION DEMOGRAPHY ..... 33
4.3 BREEDING BIOLOGY ..... 65
4.3a Phenology ..... 65
4.3b Seed production ..... 71
4.3c Seed germination requirements ..... 74
4.3d Seed bank demography ..... 76
4.3e Breeding and mating systems ..... 78
4.3f Dispersal ..... 87
4.4 PVA MODELLING ..... 90
4.5 ENVIRONMENTAL INTERACTIONS AND PLANT HEALTH ..... 92
4.5a Abiotic associations ..... 92
4.5b Translocation study of environmental boundaries ..... 101
4.5c Drought study ..... 106
4.5d Plant response to environmental variation ..... 112
4.5e Plant health ..... 113
4.5f Below ground adaptations ..... 115
4.5g Biotic interactions ..... 122
4.6 RESTORATION AND TRANSLOCATION ..... 126
4.6a Storage of propagation material for translocation ..... 126
4.6b Translocation methods ..... 129
4.7 *EX SITU* CONSERVATION ..... 130
4.7a Seed storage ..... 130
4.7b Germplasm storage ..... 130
**5 References ..... 134**

# 1 INTRODUCTION

This research report is based on the *Conservation and Restoration Research Proposal for Darwinia masonii and Lepidosperma gibsonii: An integrated research program into ex situ and in situ conservation, restoration and translocation of Darwinia masonii and Lepidosperma gibsonii 2007-2010.* August 2008. That proposal was developed by BGPA in response to the commitments of Mount Gibson Mining Limited (MGM) and Extension Hill Pty Ltd (EHPL) to fund a 3+ year research program on the declared rare flora species *Darwinia masonii* (Myrtaceae) and *Lepidosperma gibsonii* (Cyperaceae).

This research program is based on, and specifically addresses the objectives of Conditions 6.1 and 7.1 of Ministerial Statement 753, to facilitate the continued *in-situ* survival and improvement in the conservation status of *Darwinia masonii* and *Lepidosperma gibsonii* over time through targeted research which assists the development of a recovery plan for each species. The research proposal document development was also assisted through consultation with DEC Threatened Species and Communities and the EPA.

The project commenced in May 2007, and was described as having a '3 year plus' duration, with the suggestion that the program may be extended subject to achieving requirements as detailed in Ministerial Statement 753.

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## 2 EXECUTIVE SUMMARY


Summary of results

**Conservation genetics**

- *Darwinia purpurea*, and *D.* sp. Chiddarcooping are identified as the taxa most closely related to *D. masonii*.

- *Lepidosperma gibsonii* was described as a new species and formally named, with its Rare conservation status transferred from *L.* sp Mt Gibson and is most closely related to nearby populations of the *L. costale*.

- While between population genetic structuring in *Darwinia masonii* is low, some populations do not mate randomly with other populations – suggesting that there are some weak barriers to gene flow across the Mt Gibson range.

- There is very low genetic structuring between populations of *L. gibsonii*, but tests show that there are some barriers to complete gene flow across the Mt Gibson range system.

- The current population size of *L. gibsonii* is estimated to be 1.25 times greater than the current census, due to multiple genetic individuals within some clumps. Some measures of survival may over-estimate by up to 25% due to unobserved loss of genetic individuals from clumps.

**Population Demography**

- *Darwinia masonii* are long lived (likely to ca. 100 years) and fire-killed. Most individuals recruit from long-lived soil-stored seedbanks in a single cohort following fire. Limited inter-fire recruitment may occur in older populations.

- Plant size data and known population ages suggest that *D. masonii* stem diameter growth averages 0.4 $mm.yr^{-1}$ and height growth averages 2.9 $cm.yr^{-1}$. Negative height growth recorded for tagged mature plants reflects poor growth conditions in measured years.

- Post-fire seedling recruitment is high in *D. masonii*, with as many as 3.2 seedlings per pre-fire adult, although ~90% of seedlings died over their $1^{st}$ summer (albeit in a dry season).

- While mortality is rare among mature *D. masonii* plants, drought over the winter of 2010 contributed to a significant level of mortality (>10% in one site). Mortality among 4-6 year old seedlings was recorded at 2.5-15% per year.

- Reproduction commences in *D. masonii* seedlings as young as six years, but increases with plant size, in both proportion of plants flowering, and flowers per plant.

- *Lepidosperma gibsonii* individuals recruit from long-lived soil-stored seedbanks in a single post-fire cohort. There is no evidence for inter-fire recruitment. Plants are long-lived (perhaps to ca. 100 years) and about half of plants exposed to fire appear to survive and resprout.

- Plant size data and known population ages suggest that *L. gibsonii* basal diameter growth averages 2 – 2.5 mm per year for seedlings and adults. Surveys of tagged plants identified mean negative growth rates between 2007 and 2010, possibly reflecting growth conditions in these years.

- Post-fire *L. gibsonii* recruitment averaged 4.2 seedlings produced per pre-fire adult, but ~75% did not survive to 2 years. Mortality among 4-6 year old seedlings averaged 3% per year.

- Reproduction commences in *L. gibsonii* seedlings as young as six years, but increases in terms of proportion of plants flowering, and flowers per plant as plant size increases.

**Seed production and seed biology**

- *Darwinia masonii* is predominantly pollinated by a single species of Honeyeater. *D. masonii* is capable of producing low-viability, selfed seeds but the production of outcrossed seed is a critical requirement for self-sustaining populations, as there is weak evidence that selfed seed is less fit than outcrossed seed.

- *Darwinia masonii* flowering and seed production takes place over a long period in spring and early summer with the peak of ripe seed production occurring around mid November. Seed fill rates varied between years from 15 to 30% and predation rates from 6 to 22%. Seed dispersal occurs by ants. *Darwinia masonii* seed production is moderately low, varying between years from 9 to 59 seeds per plant in mature populations. Inbreeding and predation by moth larvae contribute to reduced seed quality.

- *Lepidosperma gibsonii* reproduction takes place over multiple years, with inflorescence production occurring in one year and flowering and fruit ripening occurring in the next. Pollination is via wind. If seed is produced, the period for which ripe seed can be collected from *L. gibsonii* plants is brief (one to two weeks in mid October) as good seeds fall soon after ripening.

**Seed germination and dormancy**

- Large scale production of seedlings of either species via germination of fresh or stored seed involves physical manipulation of small seeds for seed coat nicking or removal, or retrieval of seed buried for months or years.

- Germination of fresh *D. masonii* is low but can be improved by a combination of detailed physical treatments and smoke application. Germination rates of 90% have been achieved with filled seed exhumed after 9 months of burial and treated with smoke water.

- *Lepidosperma gibsonii* seed germination remains unsolved, however indications of small positive, effects of seed burial, fruit wall breakdown/removal, smoke and heat treatments are apparent. Manual seed coat removal followed by a heat treatment resulted in 60% germination.

- Seed bank demography trials established for both species are ongoing. Buried seed is in place with experiments designed to continue for up to 5 years. Results to date indicate complex germination / dormancy strategies for both species, combining a requirement for physical degradation of the seed coat, environmental (seasonal temperature) cuing – with seeds cycling in and out of dormancy, and heat- and smoke-related physiological responses.

**Environmental adaptations**

- *D. masonii* and *L. gibsonii* share with co-occurring species the drought avoiding strategy of closing down transpiration and photosynthetic function to enter a period of physiological dormancy through summer drought with the capacity to restore tissues as soils wet.

- Roots of both *D. masonii* and *L. gibsonii* have a capacity to enter large cracks, pores and fissures in regolith and may achieve considerable root depths (perhaps to >10m), but neither species showed root growth

adaptations that were significantly different from close relatives from non-BIF habitats.

**Threats**

- Grazing – presumed to be by goats and rabbits – can have a significant impact on growth and reproduction of *L. gibsonii* but has a negligible impact on *D. masonii*

- Predation of *D. masonii* seed (by larvae of an unidentified moth species) can be significant. This moth, and a gall forming insect observed on *D. masonii*, are both potentially specific to *D. masonii* and may therefore be rare and threatened species.

**Propagation, Restoration and Translocation**

- Techniques for the successful propagation of both *D. masonii* and *L. gibsonii* have been proven at both BGPA and an independent specialist nursery and involve greenstock production from cuttings (*D. masonii*) or separated clumps (*L. gibsonii*).

- Propagation from collected seed may be preferable for genetic diversity reasons and is possible for *D. masonii*, although at this stage requires some time for treatments to take place. As seed germination remains difficult for *L. gibsonii*, propagation from plant collections is the best viable option, however methods to grow plants from seed embryos in tissue culture have been developed, and provide another, more time-consuming solution.

- Species distribution models for *D. masonii* and *L. gibsonii* were able to provide good descriptions of the species' respective distributions and identified different habitat attributes for each. These models also identify localities for possible translocation sites.

- Distribution models indicate a preference of *L. gibsonii* for cooler sites and suggest that restoration surfaces should be sloped to minimise solar radiation receipt for this species. Similar models indicate broad habitat requirements for *D. masonii* (BIF rocky loam soils) but may possibly mask an association with unmapped sub-surface features.

- Translocation trials of both species utilised unmanipulated, naturally occurring substrate variation and demonstrated that both *D. masonii* and *L. gibsonii* have the ability to be planted and survive in restoration sites

although this is effectively limited to BIF rock and BIF gravel substrate sites.

- Survival of transplanted *D. masonii* greenstock averaged under 40% (at 9 months) at the best performing site (BIF rocky loam). An additional pilot trial suggests that irrigation may improve *D. masonii* survival and growth rates.

- Transplanted *L. gibsonii* survival was greatest on BIF gravel sites (70%) but was also high on BIF rock sites

- Translocation sites differed in several soil properties, of which texture, gravel/rock content, patterns of moisture content and total Nitrogen may be the most critical.

***Ex Situ* Conservation**

- Batches of 1000 filled seeds of each of *D. masonii* and *L. gibsonii* have been deposited at three (Australian and international) conservation seed storage facilities. In addition genotypes of both species are stored as live plants at two locations off-site and as seed at three secure locations off-site.

- *in vitro* culture has been achieved with both *D. masonii* and *L. gibsonii* and cryostorage is an option for long-term storage of key clonal germplasm if required.

## Summary of Recommendations

### Conservation genetics

- Investigations requiring complete mapping of individuals (e.g. mating studies) for *L. gibsonii* requires exhaustive genetic sampling within clumps to identify all individuals.

- The precautionary principle should apply to avoid mixing genotypes in restoration between respective populations of *D. masonii* or *L. gibsonii*.

### Population Demography

- Monitoring of tagged plants in plots established in this program, including post-fire plots should, continue. The monitoring program may require expansion in order to meet ministerial requirements for numbers of plants.

- Population survey should take place annually in October or November. All plants in selected, permanently marked plots should be individually tagged and measured.

- Key variables to measure in marked plots include: survival, recruitment (new plants should be tagged and recorded as found), health, herbivory, infructescence production (and seed production for *L. gibsonii*) and growth of seedlings and smaller plants.

- Annual collection of a sample of (>10) infructescences of both species from each major population to assess rates of seed predation and seed fill are also recommended.

- Established seed burial and retrieval trials with associated germination treatments should continue for at least several further years.

- Seed collection should be timed closely to ensure that collected fruits contain viable filled and un-predated seed. Ideal times appear to be mid November for *D. masonii* and mid October (in fruiting years) for *L. gibsonii*. Seed counts should take into account the low number of filled seeds per fruit, known selfing rates, and assess seed predation rates.

### Environmental Interactions

- Mapping of soil or regolith data for the region is suggested to refine distribution models to improve understanding and predictions of the habitat and restoration requirements for *D. masonii*

- Root systems could be examined in mining pit walls as they are constructed, to determine rooting depth of *D. masonii* and *L. gibsonii* and their use of surficial versus deeper layers in the soil profile. Results would inform requirements for restoration substrates.

**Threats and *Ex Situ* Conservation**

- Manage populations of goats and rabbits, and monitor herbivory impacts of macropods on *L. gibsonii*.

- Ensure habitat requirements for key *D. masonii* pollinators are retained.

- Identify the seed-eating moth species and survey for its occurrence in co-occurring species and related *Darwinia* species.

- *Ex situ* collections of live plant and seed material and multiple (>100 for live plants) genotypes should be maintained, monitored and supplemented as required

**Restoration / Translocation**

- Samples of large numbers of filled seed can be assembled for *D. masonii* and *L. gibsonii* (in years in which it produces seed) with careful attention to timing of seed maturation, predation rates and seed screening and cleaning.

- Propagation of live plant material from wild collections and nursery stock are likely the most cost effective approach for the short-medium term storage and production of plants for restoration purposes.

- For *D. masonii*, further research into seedling production under lab, glasshouse or field conditions appears promising and may provide a preferable approach to providing a genetically diverse and numerous source of restoration plants.

- Experiments manipulating restoration substrates using mine waste components or other available and appropriate materials are recommended as mining construction commences. Record plant growth and survival.

- Sand and clay materials may not be effective restoration materials for *D. masonii* and *L. gibsonii*, although mixing clays with rock and/or gravel may be worth trialling. Final restored structure surface must incorporate a large proportion of BIF rock or gravel for successful restoration of both species.

- Trials in which *D. masonii* and *L. gibsonii* are translocated into restoration substrates designed and constructed with varying amounts of rock and gravels, and with rocks at varying depths are recommended.

- Restoration areas for *L. gibsonii* should be shaped as slopes or gullies oriented with lower radiation receipt. Restoration trials for *L. gibsonii* should include treatments varying shade and moisture.

- Restoration areas for *D. masonii* may not require particular topographies, but attention to soil requirements may be important. Restoration trials for *D. masonii* should include treatments varying degrees of soil depth and rockiness.

- Restoration efforts must include adequate community context e.g. ensuring adequate habitat for White-fronted Honeyeaters and seed dispersing ant species.

# 3 PROJECT BACKGROUND

Mount Gibson and the adjoining ridges lie 350 km north east of Perth in Western Australia. The range is largely composed of banded ironstone (BIF), with significant deposits of both hematite and magnetite. The range has been investigated for many years with the view to extracting iron ore.

The project was assessed as a Public Environmental Review (PER) under Part IV of the Western Australian *Environmental Protection Act* 1986. In addition the proposal is considered to be a controlled action under the Commonwealth *Environmental Protection and Biodiversity Conservation Act* 1999

The PER was released for public review from 18 April to 30 May 2006. The Environmental Protection Authority (EPA) released its Report and Recommendations on the Mt Gibson Iron Ore Mine and Infrastructure Project (Bulletin 1242) on 27 November 2006.

The EPA recommended that the project be given approval subject to a number of conditions. The Mt Gibson Iron Ore Mine and infrastructure Project was approved by the Western Australian Minister for the Environment on 24 October 2007 (Ministerial Statement 753). The project received approval to undertake a controlled action under the *Environmental Protection and Biodiversity Conservation Act 1999* on the 18 December 2007.

During the assessment process, a species of Declared Rare Flora (*Darwinia masonii*) was known to be endemic to the Mt Gibson Range, and the then project proponent, Mount Gibson Mining Limited contracted ATA Environmental to survey the plants, and BGPA to investigate critical biological factors relating to the rarity and reproductive potential of the species.

In early 2006, a second species endemic to the range was discovered, which was referred to in the EPA Bulletin 1242 as *Lepidosperma* sp. Mt Gibson, which has since been described as *Lepidosperma gibsonii* R.L. Barrett (Barrett, 2007). ATA Environmental (now Coffey Environments) and BGPA were again contracted to conduct similar preliminary research for *Lepidosperma gibsonii* as previously done for *Darwinia masonii*.

In August 2006, Mount Gibson Mining Limited sold Asia Iron Holdings Limited and Extension Hill Pty Ltd including the mining tenements and overall project to Sinom Investments but retained the rights to mine hematite ores verses the magnetite ores that were to be mined by the new independent company.

Since this time and following State Ministerial approval (24 October 2007) and Commonwealth Approval (18 December 2007), Mount Gibson Mining Limited (MGM) and Extension Hill Pty Ltd (EHPL) have become joint proponents in the Mount Gibson Iron Ore Mine and Infrastructure Project defined by Ministerial Statement 753 (WA Environmental Protection Act, 1986) and the Commonwealth approval under the Environmental Protection and Biodiversity Conservation Act, 1999. The proponents are now developing an iron ore mine at the Extension Hill deposit in the northern part of the Mt Gibson ranges consisting of both hematite and magnetite mining infrastructure (MGM and EHPL respectively). Expansions of the project's footprint were approved 20 February 2008.

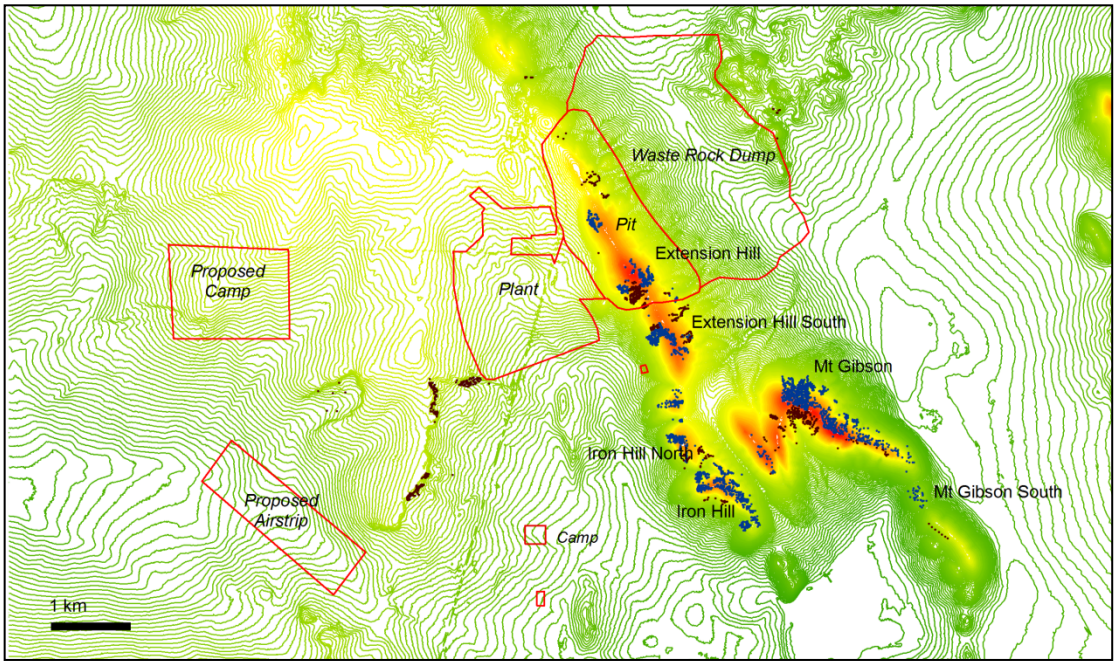



**Figure 1** Major features of the study area including proposed (approved) mining project footprint, topography (1m contours), major peaks and the distribution of *L. gibsonii* (brown dots) and *D. masonii* (blue dots)

### 3.1 RELATED DOCUMENTS

Interim Recovery Plans (IRP's) have been prepared for *Darwinia masonii* and *Lepidosperma gibsonii* which detail the recovery actions and the monitoring to be undertaken for each species as required by Conditions 6.1.1, 6.2, 7.1.1 and 7.2 of Ministerial Statement 753.

An Environmental Management Plan has been prepared for the Mt Gibson Iron Ore Mine and Infrastructure Project that details management measures to minimize the direct and indirect impacts of mining on significant flora including

*Darwinia masonii* and *Lepidosperma gibsonii* as required by Condition 8 of Ministerial Statement 753.

## 3.2 OTHER RESEARCH

The research program reported here is devoted specifically to the Declared Rare Flora (DRF) species *Darwinia masonii* and *Lepidosperma gibsonii.* However, other research initiatives are required to meet Conditions 6.1.5 and 7.1.5 (other impacts on DRF, including from dust) and 14 (Closure) of Ministerial Statement 753. In response to these requirements, BGPA has prepared and submitted a **Proposal for research into the restoration of plant communities in the Extension Hill – Mt Gibson iron ore mining project** (submitted February 2008, updated February 2010) as well as a **Proposal for research into the affects of dust on rare plants** (submitted July 2008) to EHPL and MGM. Funding of a 2008 version of the restoration research plan was agreed by both EHPL and MGM subject to final approval of mining and the (subsequently delayed) commencement of operations. This community restoration research was specifically noted in the ***Darwinia masonii*** **and** ***Lepidosperma gibsonii*** **Conservation and Restoration Research Plan** (i.e. the plan outlining the research presented here and signed-off by DEC) as a necessary research component additional to the work covered in the plan.

The results of the research program presented here show that some research areas require ongoing investigation for satisfactory conclusion in relation to Conditions 6.1.1, 6.2, 7.1.1 and 7.2 of Ministerial Statement 753. In particular, the strong inter-annual variation observed in key population parameters (i.e. growth, survival and seed production rates) means that long-term population monitoring is required for determination of their average values and patterns of variability. This long-term monitoring is essential in order to determine whether future observed fluctuations result from mining impacts or natural variation. The same data are also essential for tests of population viability and extinction likelihoods in response to impacts such as fire, herbivory or continued drought (or similar climatic extreme), or mining impacts such as population loss, or augmentation through restoration. A program for continuation of the DRF research presented here – ***Proposal for continuation of Extension Hill – Mt Gibson DRF Research Program*** (January 2010, updated May 2010) – has been prepared by BGPA and submitted to EHPL and MGM.

Details of requirements for monitoring of the health of, and mining impacts on, DRF populations (including a specified proportion of individuals) are given in

Ministerial Statement 753. As this monitoring does not constitute research per se, it was never an objective of the BGPA research program to meet these requirements. Nevertheless, monitoring of these parameters for research objectives has been a component of the work presented here, although not to the requirements (in terms of number of individuals represented) of the Ministerial Statement in several details. Additional monitoring will be required by EHPL and MGM to meet these requirements.

# 4 FINDINGS

## 4.1 CONSERVATION GENETICS

### 4.1a Phylogenetic context

***Darwinia masonii***

Charles Gardner, when describing *Darwinia masonii* in 1964, noted the pendulous flower heads and long marginal bracts, and concluded that it was closely related to the Stirling Range species *Darwinia leiostyla*. No analysis of relationships within *Darwinia* has been undertaken since that time (other than speculations on the relationships of a few individual species).

In order to identify appropriate comparisons for the assessment of genetic diversity and comparative ecology in *D. masonii*, a thorough analysis of phylogenetic relationships in the genus *Darwinia* was undertaken, including most species of *Darwinia* in south-west WA, and several species of the disjunct "*D. fascicularis*-group" in New South Wales and South Australia. Two gene regions were used in order to detect incongruent signal resulting from gene trees vs species trees: the nuclear ribosomal External Transcribed Spacer (ETS), and the chloroplast trnK intron (including the *mat*K gene).

Analysis of chloroplast and nuclear genes showed significant incongruence at many of the upper nodes in the tree (suggesting either incomplete lineage sorting or ancient hybridisation), however most species-groups identified had identical composition. In particular, the position of *D. masonii* clearly resolved with neither the (monophyletic) Stirling Range Bells, nor the group around *D. helichrysoides*/*D. neildiana*, but rather with a group of unassuming *Darwinia* species of the WA Northern Sandplain and Wheatbelt regions, including *D. purpurea, D. acerosa*, and the undescribed species *D.* sp. Chiddarcooping (S.D. Hopper 6944). Each of these three species is a spreading shrub with upright to sub-pendulous flower heads and short bracts and styles, unlike *D. masonii* which is upright, with pendulous flower heads and long bracts and styles. Optimising morphological characters on the phylogeny, it is clear that both pendulous flowers and long styles and bracts have evolved several times independently in the genus *Darwinia*, presumably to improve pollination success by honeyeaters. *Darwinia masonii* has thus evolved its defining floral characteristics from less specialised forms like *D. purpurea*. Relationships between *D. masonii*, *D. purpurea, D. acerosa*, and *D.* sp. Chiddarcooping were unresolved by either phylogenetic marker, indicating that they are closely related, and possibly speciated allopatrically, through isolation and subsequent adaptation of a previously widespread species.

**Summary**

- *Darwinia purpurea*, *D. acerosa* and *D.* sp. Chiddarcooping were identified as the taxa most closely related to *D. masonii* and have subsequently been employed as comparison species for several studies in later sections, including genetic diversity analyses and root adaptations.

***Lepidosperma gibsonii***

*Lepidosperma gibsonii* was first identified from collected material from Extension Hill. From its discovery in 2006 the taxa was informally named as *Lepidosperma* sp. Mt Gibson (R. Meissner & Y. Caruso 3), but in late 2007 was formally described and published as the new species, *Lepidosperma gibsonii* R.L.Barrett, in a special edition of the journal *Nuytsia* devoted to new BIF associated species (Barrett 2007).

*Lepidosperma gibsonii* belongs to a morphologically depauperate group of grass-like plants, whose relationships are especially difficult to discern due to the lack of morphological variation. Genetic methods are therefore critical to identify related taxa. *Lepidosperma* species with similar morphology were sampled across south-west WA, focussing on populations within 200 km of MT Gibson. Two genes were used to assess relationships, the nuclear ribosomal External Transcribed Spacer (ETS) and the chloroplast *trn*L inton + *trn*L-*trn*F spacer. The latter proved to be less variable than ETS, and so sampling was less comprehensive for that region, with ETS being used only for subsets of taxa within clades.

The molecular analyses found that *L. gibsonii* was clearly closely related to a group of taxa around *L. costale*, and only more distantly related to the morphologically similar species *L. ferricola*. Further sampling by BGPA has identified populations of the *L. costale* complex from Mullewa and Mt Karara to Paynes Find, south to York and east to near Southern Cross. Both between- and within-population diversity in this species complex can be considerable, and further studies are required to full elucidate their taxonomy. Only *L. gibsonii* can be easily distinguished, being the only member of the complex with rounded, terete (or sub-terete) culms; all other populations have sharply angled stems. A separately-funded project at BGPA has investigated ploidy-level differences within the *L. costale* complex, demonstrating that most populations are tetraploid, some populations are of allopolyploid-hybrid origin, and that diploids are almost entirely restricted to the semi-arid interzone between Mt Gibson, Mt Karara and Wubin (Figure 2). Due to different breeding systems in the tetraploid populations (wholly or partly

agamospermous, producing seeds without recombination), only the diploid populations are useful for comparative genetic diversity in *L. gibsonii*.

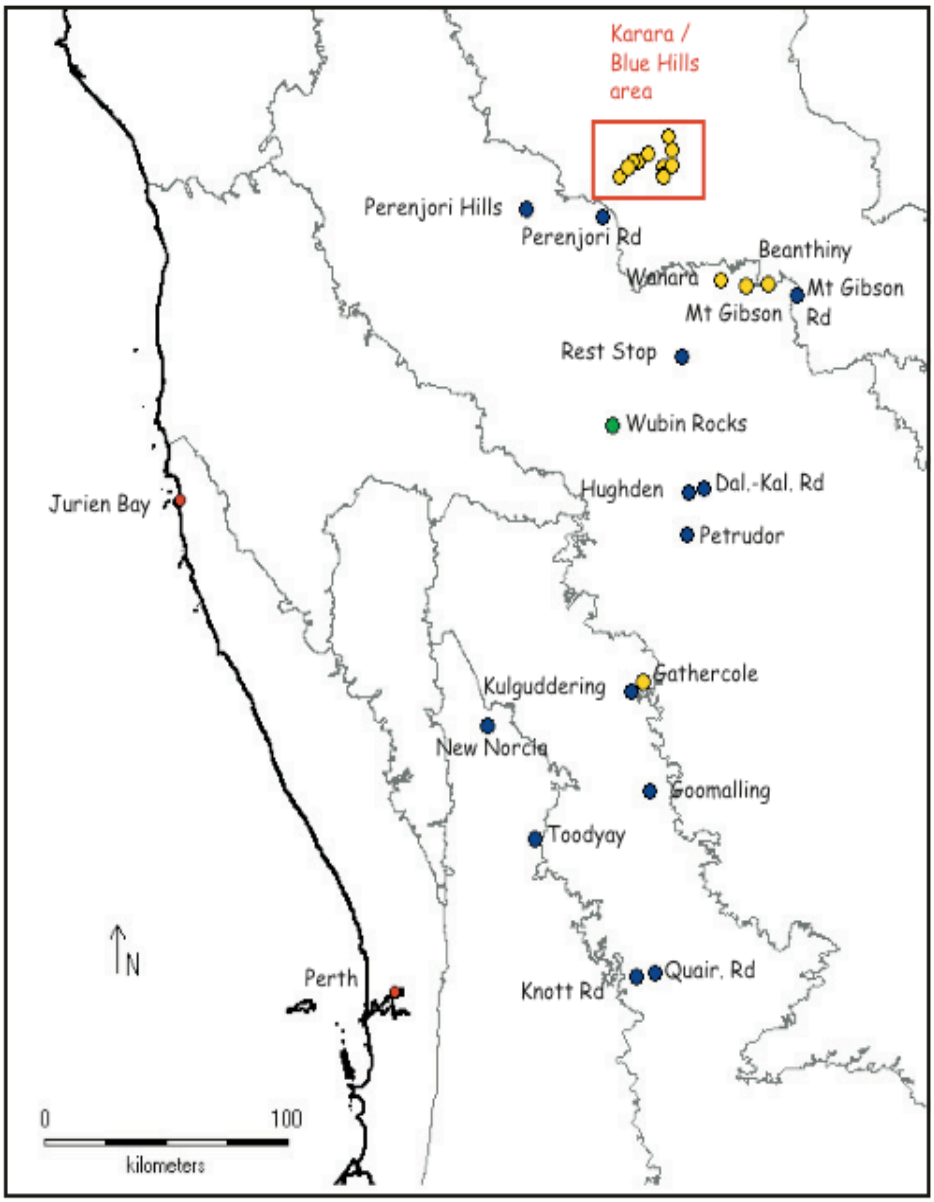



**Figure 2.** Map of genome content levels within the *Lepidosperma costale* complex. Yellow circles indicate populations with normal (diploid) DNA content. Blue indicates populations containing only individuals with double the normal DNA content per cell (tetraploid). The green circle (Wubin population) contains both diploid and tetraploid plants – extensive study of this population indicates that diploids and tetraploids are physically separated, and only a single triploid 'hybrid' was located. Diploid populations presumably gave rise to the now widespread tetraploid lineages, but are now almost confined to the driest area of the distribution of the species-complex. Some populations wholly or partly reproduce by agamospery (producing seeds without recombination). Other tetraploid populations are allotetraploid hybrids, with half the genome having come from a species outside of the *L. costale*-complex (at least two other species have contributed to this process in different locations).

**Summary**

- *Lepidosperma gibsonii* was described as a new species and formally named, with the conservation status of rare transferred to it from *L.* sp Mt Gibson.

- *Lepidosperma gibsonii* is most closely related genetically to populations of the *L. costale* complex around Mt Karara, Beanthiny Hill and Wubin. Comparisons of genetic diversity and adaptations were concentrated on these species.

### 4.1b Landscape scale genetic structure

***Darwinia masonii***

The initial genetic survey of *Darwinia masonii* (BGPA 2005, following a 6-month initial genetic survey) was based on 75 samples from four populations on the Mt Gibson range system, using the AFLP (Amplified Fragment Length Polymorphism) fingerprinting technique. This study found both limited diversity (with 50.6% of markers polymorphic, very low for AFLP), and low population differentiation (AMOVA found that 94% of genetic variation was contained within populations, and just 6% between populations). As recognised in the report, and also raised subsequently by reviewers from the Dept. of Environment and Conservation (DEC), the low variability observed in the AFLP markers lowered the power to test for population differentiation in this species, which was further hampered by insufficient sample size in the preliminary study, both in number of samples and number of populations. As a result, a more powerful genetic fingerprinting technique, simple-sequence repeats (SSR), more commonly known as microsatellites was employed following development of the marker system; this is the same type of genetic marker as used for *Lepidosperma gibsonii*.

*SSR (Microsatellite) marker Development*

Genomic DNA was extracted in bulk (100 ug of DNA total), and sent to Genetic Identification Services in the US for cutting, inserting into bacterial libraries, cloned, enriched for microsatellite-containing sequences, and sequenced. Microsatellite-containing sequences were then screened for the most appropriate microsatellite motifs (including a range of di- and tri-nucleotide motifs, while avoiding flanking regions containing long mono-nucleotide repeats as they can confound scoring). Primers were developed from the sequences to amplify the target loci, and these primers were screened for amplification reliability, copy number, and degree of stutter (an artefact that can prevent accurate scoring). A total of 14 microsatellite loci

were finally produced, which were used in various analyses of genetic diversity and mating system in *D. masonii*.

*Population genetic structure*

A total of 179 samples from seven populations of *D. masonii* on the Mt Gibson range (Figure 3) were taken from young leaf tips and stored at -178°C in a liquid-nitrogen dry-shipper in the field, then placed in a -80°C freezer awaiting extraction. DNA was extracted following the Carlson-Qiagen extraction procedure as outlined in the Phase One study (BGPA 2005).

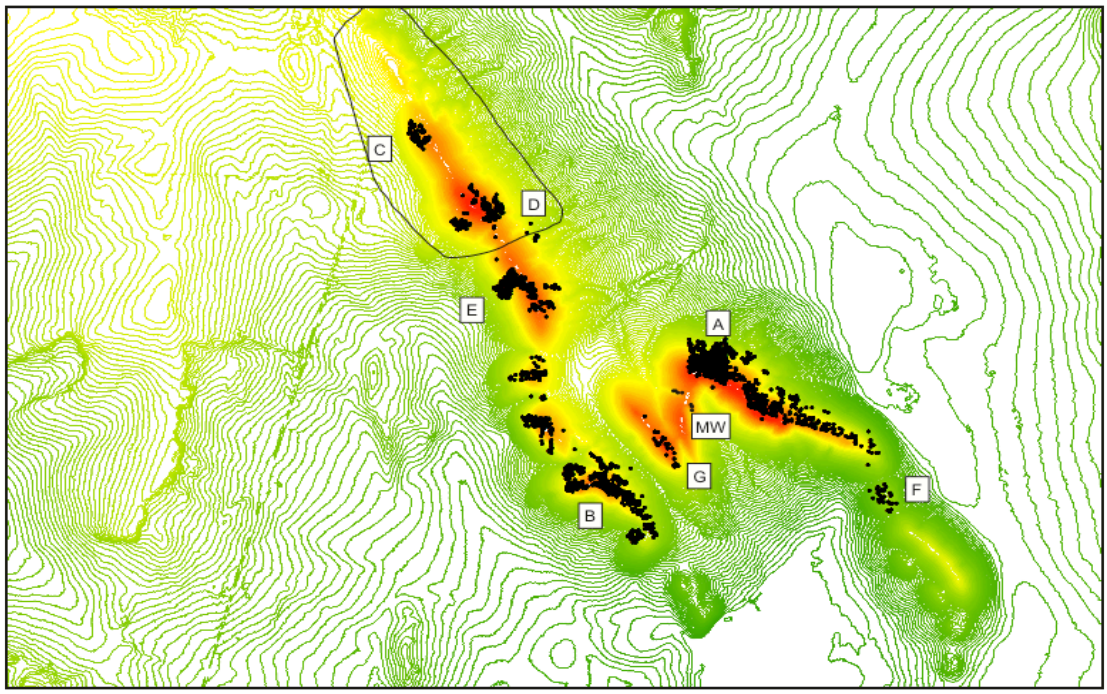



**Figure 3.** Distribution of *Darwinia masonii* (black dots) on the Mt Gibson range, and collection localities labelled by population code. Codes – A: Mt Gibson, B: Iron Hill, D: Extension Hill, E: Extension Hill South, F: Mt Gibson South, G: Iron Hill East, MW: between Mt Gibson and Iron Hill East. Black line shows approximate position of the pit.

Analysis of Molecular variance partitioned 94% of variation within populations, and 6% between populations, indicating weak population structure (as can be seen graphically in Figure 4, where samples from different populations do not group together, but are instead completely intermixed). This is the same result (6% between-population variation) obtained with AFLP data from fewer populations. In contrast to the previous AFLP study, which showed no significantly genetically distinct populations, pairwise permutation tests (

Table 1) between all populations show that two populations (on Extension Hill South and Mt Gibson South – E and F respectively in Figure 1) are statistically supported (at $p < 0.001$) as being genetically 'isolated' from each other and all remaining populations. In this context, 'isolated' means not mating randomly with other populations, with number of possible explanations. Aside from these two populations, other populations are scarcely significantly different from a single panmictic, interbreeding population.

Possible causes of divergence within populations: The population Mt Gibson South ("F") is somewhat disjunct and at the southern end of the range, as expected for a population diverging in isolation; however, the population has clearly not been burnt for > 50 years, unlike most other populations, and as a result the observed non-random mating could be an artefact of sampling different generations. The population on Extension Hill South ("E") is close to that the population on Extension Hill, occupies an intermediate position on the western ridge, and the observed result is surprising. The observed weak departure from non-random mating could be due to differences in population age, or some populations could be experiencing differential selection at loci linked to some microsatellite markers. Sampled plants came from a variety of plant ages, fire history, and substrate, as this population extends from almost bare BIF cliffs to laterite at the range base.

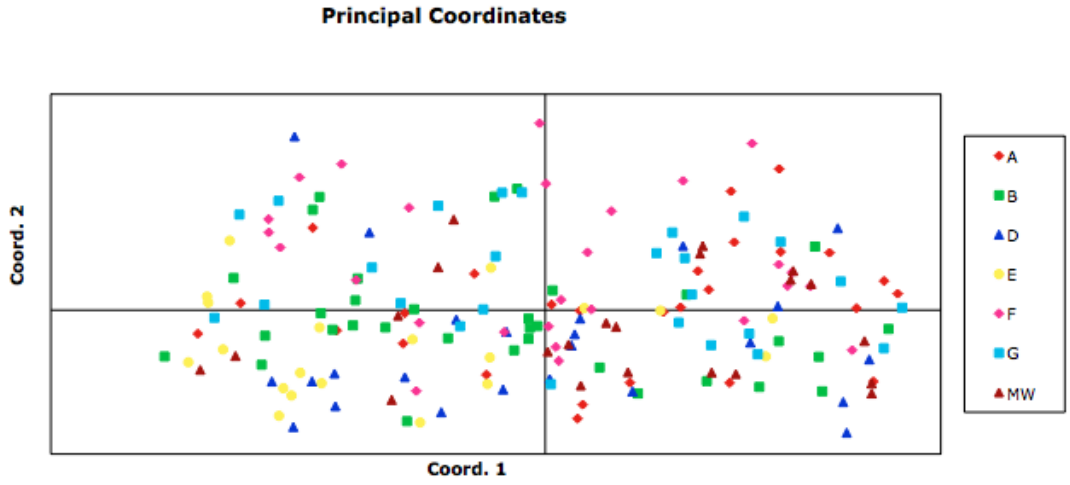



**Figure 4** Principal Co-ordinates analyses of samples from seven populations of *D. masonii* showing weak differentiation between localities. Codes as previous figure. In this figure, samples placed close together are more closely related. The figure shows no strong clustering of individuals within populations; formal statistical tests demonstrated that only a few pairwise population comparisons are statistically distinct, with no geographic pattern.

**Table 1.** Pairwise permutation test of population differentiation. **Bold**: significant at p < 0.001, *italics* significant at p <0.005. Codes – A: Mt Gibson, B: Iron Hill, D: Extension Hill, E: Extension Hill South, F: Mt Gibson South, G: Iron Hill East, MW: between Mt Gibson and Iron Hill East. Populations E and F are significantly supported as departing from random mating with other populations; occasional other pairwise comparisons are also significant.

| A | B | D | E | F | G | MW | |
|---|---|---|---|---|---|---|---|
| | **0.001** | *0.004* | **0.001** | *0.002* | 0.076 | 0.425 | **A** |
| | | 0.087 | **0.001** | **0.001** | 0.048 | 0.017 | **B** |
| | | | *0.002* | **0.001** | *0.002* | 0.119 | **D** |
| | | | | **0.001** | **0.001** | **0.001** | **E** |
| | | | | | *0.004* | **0.001** | **F** |
| | | | | | | 0.071 | **G** |
| | | | | | | | **MW** |

*Population genetic diversity – within D. masonii*

Expected heterozygosity, and fixation Index was estimated for all seven sampled *D. masonii* populations (Table 2). All were very similar in levels of diversity (Unbiased Heterozygosity estimates vary between 0.600-0.657). Fixation index for the species was 0.105 ± 0.024, indicating a low but significant level of inbreeding. This result is further corroborated below (section **4.3e Breeding and Mating systems**).

**Table 2.** Heterozygosity and fixation index estimates from populations of *Darwinia masonii.* Population codes as previous tables and figures.

| Pop | Ho | He | UHe | F |
|---|---|---|---|---|
| **A** | 0.487 ± 0.09 | 0.593 ± 0.115 | 0.605 ± 0.117 | 0.144 ± 0.041 |
| **B** | 0.59 ± 0.102 | 0.647 ± 0.109 | 0.657 ± 0.111 | 0.066 ± 0.048 |
| **D** | 0.474 ± 0.106 | 0.601 ± 0.123 | 0.614 ± 0.126 | 0.216 ± 0.057 |
| **E** | 0.657 ± 0.092 | 0.625 ± 0.088 | 0.642 ± 0.091 | -0.067 ± 0.056 |
| **F** | 0.537 ± 0.094 | 0.629 ± 0.089 | 0.64 ± 0.091 | 0.172 ± 0.076 |
| **G** | 0.566 ± 0.126 | 0.63 ± 0.104 | 0.642 ± 0.106 | 0.149 ± 0.089 |
| **MW** | 0.533 ± 0.11 | 0.586 ± 0.117 | 0.6 ± 0.12 | 0.077 ± 0.031 |
| | | | | |
| **Total** | 0.549 ± 0.037 | 0.616 ± 0.037 | 0.629 ± 0.038 | 0.105 ± 0.024 |

*Population genetic diversity – comparison with other species*

The preliminary genetic survey was unable to adequately reference the “low” AFLP variation due to the lack of a comparable study in *Darwinia*. It has been suggested that low chromosome number can decrease genetic variability (e.g. Diuris, Indsto et al 2009); since *Darwinia* species are known to show a dysploid chromosome-reduction series (Rye 1981, Rye & James 1990), this is one possible reason for the low observed diversity; the alternative hypothesis is a past low population size (population bottleneck) which caused loss of

genetic diversity. The inability to distinguish between these scenarios was raised as a significant concern by DEC reviewers of the preliminary report. It was therefore necessary to reference the diversity in *D. masonii* with another species. Following the discovery through the phylogenetic research above, it was decided to use the closest relative of *D. masonii*, *D. purpurea*, as the comparative species. *Darwinia purpurea* is a relatively widespread species of sandplain and gravel soils, extending from near Perenjori and Mt Gibson South-East to about Warralakin (with a single disjunct population c. 80 km north of Mt Gibson at Kirkalocka Station on an isolated yellow sand lens). The potentially distinct species known by the informal phrase-name "*Darwinia* sp. Chiddarcooping (S.D. Hopper 6944)" was also included, due to apparent intergrades between it and *D. purpurea*, and the tendency for it to grow in isolated populations on granite rocks, and might therefore be a more appropriate comparison for *D. masonii* than the less habitat-constricted *D. purpurea*. The relative distribution of these species, and the related *D. acerosa*, is shown in Figure 5

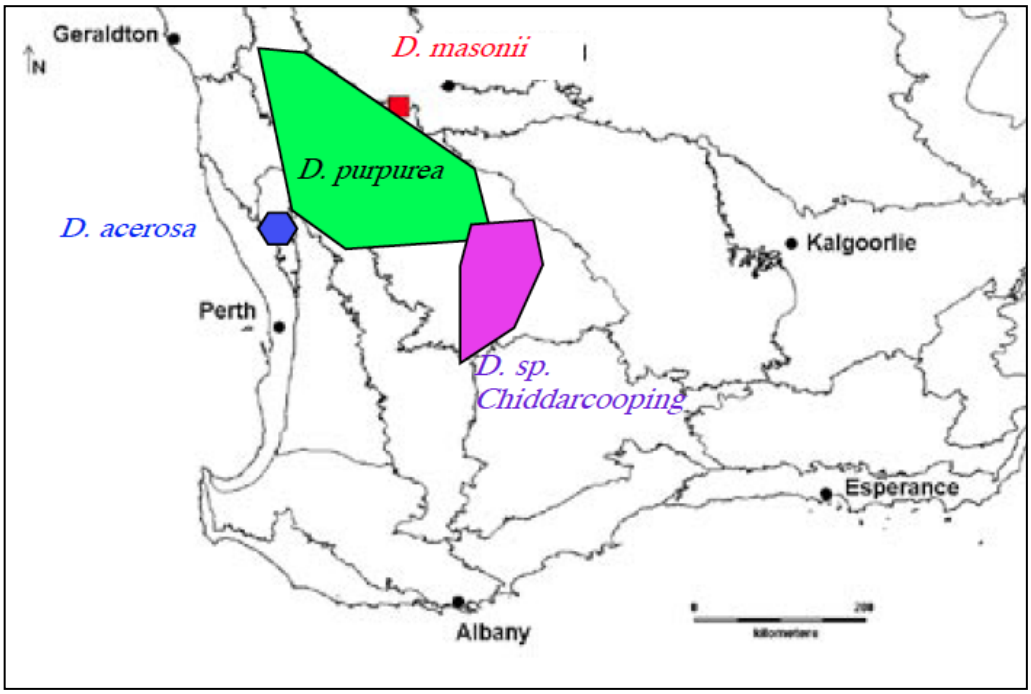



**Figure 5.** Distribution of *Darwinia masonii* and closely related species: *D. purpurea, D. acerosa* and *D.* sp. Chiddarcooping.

A total of 401 plants from thirteen populations of the *D. purpurea* / *D*. sp. Chiddarcooping species-group were sampled (Table 3), and genotyped using the microsatellite loci described above. Genetic diversity within and between these populations were compared to the diversity in all sampled *D. masonii* populations (as referred to above). Only one population of *D. masonii* (Iron

Hill) was used in the all-taxa population structure analysis (PCA) to allow comparisons of similar sampling numbers and sampling density (Figure 6).

**Table 3** Average genetic diversity within sampled populations of *Darwinia masonii*, *D. purpurea* and *D. sp.* Chiddarcooping.

| Population | Ho | He | UHe | F |
|---|---|---|---|---|
| ***D. sp. Chiddarcooping* populations** | | | | |
| **Corrigin** | 0.111 ± 0.049 | 0.214 ± 0.093 | 0.217 ± 0.094 | 0.365 ± 0.116 |
| **Billy** | 0.693 ± 0.058 | 0.750 ± 0.055 | 0.762 ± 0.056 | 0.077 ± 0.028 |
| **Chidd** | 0.670 ± 0.063 | 0.661 ± 0.058 | 0.672 ± 0.059 | -0.020 ± 0.054 |
| **Wara** | 0.498 ± 0.093 | 0.651 ± 0.047 | 0.662 ± 0.048 | 0.243 ± 0.128 |
| | | | | |
| ***Darwinia purpurea* populations** | | | | |
| **Yorkrak** | 0.583 ± 0.059 | 0.670 ± 0.051 | 0.684 ± 0.052 | 0.109 ± 0.094 |
| **Burakin** | 0.722 ± 0.024 | 0.794 ± 0.024 | 0.807 ± 0.024 | 0.088 ± 0.035 |
| **Koorda** | 0.674 ± 0.093 | 0.762 ± 0.081 | 0.775 ± 0.082 | 0.103 ± 0.082 |
| **Korakadine** | 0.566 ± 0.086 | 0.577 ± 0.088 | 0.587 ± 0.090 | 0.007 ± 0.030 |
| **Ballidu** | 0.722 ± 0.027 | 0.775 ± 0.050 | 0.791 ± 0.051 | 0.056 ± 0.045 |
| **Dal-Kal** | 0.741 ± 0.069 | 0.758 ± 0.057 | 0.775 ± 0.058 | 0.029 ± 0.030 |
| **Bunjil** | 0.396 ± 0.090 | 0.434 ± 0.084 | 0.444 ± 0.087 | 0.184 ± 0.180 |
| **Latham** | 0.645 ± 0.080 | 0.684 ± 0.071 | 0.696 ± 0.072 | 0.066 ± 0.039 |
| **Wubin** | 0.806 ± 0.027 | 0.801 ± 0.034 | 0.822 ± 0.035 | -0.008 ± 0.019 |
| | | | | |
| ***Darwinia masonii* populations** | | | | |
| **A** | 0.487 ± 0.09 | 0.593 ± 0.115 | 0.605 ± 0.117 | 0.144 ± 0.041 |
| **B** | 0.590 ± 0.102 | 0.647 ± 0.109 | 0.657 ± 0.111 | 0.066 ± 0.048 |
| **D** | 0.474 ± 0.106 | 0.601 ± 0.123 | 0.614 ± 0.126 | 0.216 ± 0.057 |
| **E** | 0.657 ± 0.092 | 0.625 ± 0.088 | 0.642 ± 0.091 | -0.067 ± 0.056 |
| **F** | 0.537 ± 0.094 | 0.629 ± 0.089 | 0.640 ± 0.091 | 0.172 ± 0.076 |
| **G** | 0.566 ± 0.126 | 0.630 ± 0.104 | 0.642 ± 0.106 | 0.149 ± 0.089 |
| **MW** | 0.533 ± 0.110 | 0.586 ± 0.117 | 0.600 ± 0.120 | 0.077 ± 0.031 |
| **Total** | 0.549 ± 0.037 | 0.616 ± 0.037 | 0.629 ± 0.038 | 0.105 ± 0.024 |

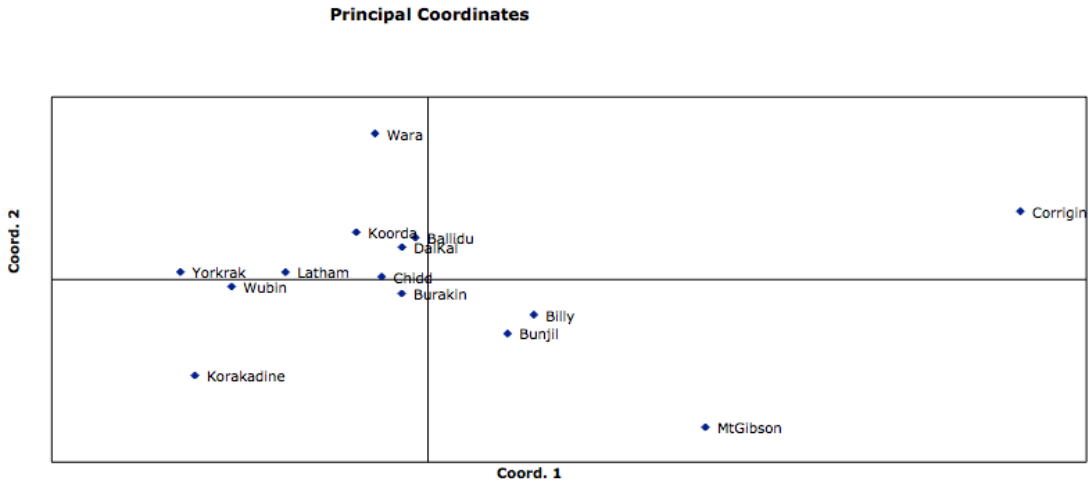



**Figure 6** PCA analysis showing genetic relationships among sampled populations of *Darwinia purpurea*, *D. sp.* Chiddarcooping and *D. masonii* (as "Mt Gibson"), using Nei's genetic distance as a measure of divergence between populations. In this figure, sites located close together are more closely related. The two most divergent populations are the Corrigin population, which may represent a distinct species, and

*D. masonii*, with the *D. purpurea* and *D.* sp. Chiddarcooping populations forming a cluster, with little differentiation between the two species.

*Results: Darwinia masonii* contains comparable (but slightly lower than average) microsatellite diversity relative to other populations in this species-group (Table 3). For example unbiased heterozygosity estimates in *D. masonii* range between 0.600 and 0.657, compared with 0.587-0.807 for *D. purpurea / D.* sp. Chiddarcooping populations, (excluding two populations with abnormally low diversity discussed next). The only two populations showing a significant reduction in genetic diversity were the Corrigin and Bunjil populations. The Bunjil population is in a small, highly disturbed patch of remnant vegetation with only a few scattered plants, and has presumably lost some of its diversity through recent reduction in population size. The Corrigin population is restricted to a small area on a single granite rock, contains less than 100 plants, and is geographically disjunct from other members of the *D. purpurea* / *D.* sp. Chiddarcooping complex. It also shows morphological differences to all other populations and species of *Darwinia*, and may warrant recognition as a distinct species. In the context of this study it serves as a reference comparison as a population that has presumably lost much of its genetic diversity though inbreeding due to small population size (an alternative hypothesis is that a rare long-distance dispersal event occurred, and that the Corrigin population is showing the effects of a recent founder population; however, given the number of unique alleles in this population, and the divergent morphology of its individuals, it is more likely to be a in isolated relictual population).

*Darwinia masonii* shows no indication of recent inbreeding depression, unlike the Bunjil and Corrigin populations discussed above.

**Summary**

- The more powerful tests of population-genetic structure carried out here (relative to the earlier study) is mostly in agreement with the preliminary result using a different marker technique, especially in the level of population differentiation observed.

- In general, there appears to be little genetic structuring between populations of *Darwinia masonii*, (94% of genetic variation is partitioned within populations) . However pairwise tests show that some populations are statistically supported as non-randomly mating with other populations with the more powerful microsatellite analysis. This suggests that there are some barriers to complete gene flow across the Mt Gibson range system, and that the precautionary principle should apply to avoid mixing genotypes between populations without careful consideration of consequences.

***Lepidosperma gibsonii***

The initial genetic survey of *Lepidosperma gibsonii* (BGPA 2006, following a 3-month initial genetic survey using microsatellites developed for that study) was based on 145 samples from seven populations on the Mt Gibson range system. This study found high levels of microsatellite variation, and low population differentiation (AMOVA analyses partitioned 98% of genetic variation within populations, and just 2% between populations).

Subsequently to that report, several populations of *Lepidosperma* were found by BGPA staff, and surveyed by ATA environmental / Coffey Environments (populations EFN, EFS, WC, WD and MGS in Figure 7). These populations were off the Mt Gibson Range, except in the case of the population on Mt Gibson South, at the extreme southern end of the range; all were in habitats not initially recognised as being suitable for *L. gibsonii*, and so were not discovered in the initial, extensive but time-limited survey.

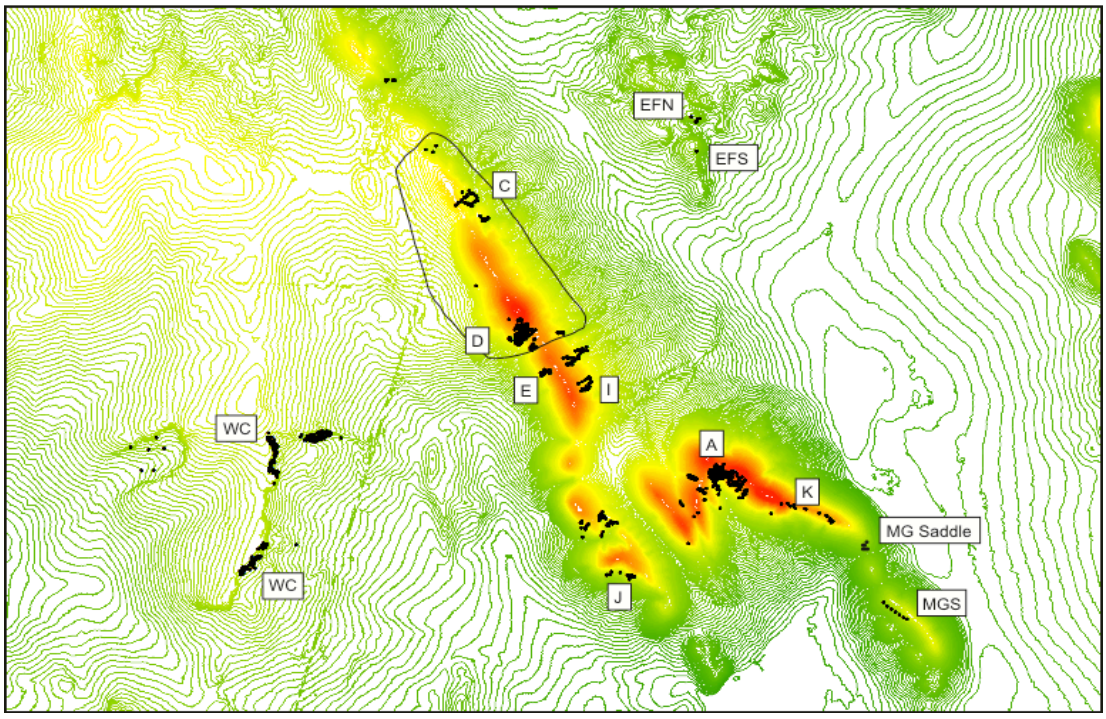



**Figure 7.** Distribution of *Lepidosperma gibsonii* (black dots), showing populations sampled in the genetic survey, and population codes: A - Mt Gibson, C- Extension Hill North, D – Extension Hill, E – Extension Hill South (west side), I - Extension Hill South (east side), J – Iron Hill, K – Mt Gibson (south end), MG Saddle – Saddle between Mt Gibson and Mt Gibson South, MGS – Mt Gibson South, EFN – Emu Fence North, EFS – Emu Fence south, WC – western breakaway north end, WD – western breakaway south end. Black line shows approximate position of the pit.

Samples from an additional six populations were collected, and genotyped using the procedure developed earlier. A total of 292 samples from 13

populations were analysed for population genetic structure (the degree of differentiation between populations, indicating the degree of dispersal of pollen and pores between populations), and diversity.

*Population structure*

Analysis of Molecular variance partitioned 96% of variation within populations, and 4% between populations, indicating weak population structure (as can be seen graphically in Figure 8, where samples belonging to the same population do not group together, but are instead completely intermixed, ie. individuals are just as closely related to individuals in other populations as they are to individuals in the same population). In contrast to the previous study, which examined half the number of populations and showed no significantly genetically distinct populations, pairwise permutation tests between populations (Table 4) show a few significant comparisons, in particular from that population on Mt Gibson Saddle, (MGSaddle respectively in Figure 7) which is statistically supported (at $p < 0.001$) as being genetically 'isolated' from nearly all remaining populations. In this context, 'isolated' means not mating randomly with other populations, due to a number of possible explanations. The most likely explanations are physical isolation, inbreeding in small populations, or strong selection at one or more linked loci. The population at the Mt Gibson Saddle is only moderately isolated from other populations, and geographically intermediate between populations that are genetically uniform. Neither of the populations (C and D) to be impacted by the pit on Extension Hill are supported as genetically distinct from other populations (except the Mt Gibson Saddle population as previously discussed, and also the population on the southern end of Extension hill from populations at the extreme end of the range (Mt Gibson and Mt Gibson South).

**Table 4** Pairwise permutation test of population differentiation. **Bold**: significant at $p < 0.001$. Codes – MG - Mt Gibson, C- Extension Hill North, D – Extension Hill, E – Extension Hill South (west side), I - Extension Hill South (east side), J – Iron Hill, K – Mt Gibson (south end), MG Saddle – Saddle between Mt Gibson and Mt Gibson South, MGS – Mt Gibson South, EFN – Emu Fence North, EFS – Emu Fence south, WC – western breakaway north end, WD – western breakaway south end.

| EFN | EFS | D | C | I | J | K | MG | MGS | MGSaddle | WC | WD | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.001** | 0.012 | 0.002 | 0.004 | 0.109 | 0.165 | 0.257 | 0.038 | 0.005 | **0.001** | 0.007 | 0.050 | **E** |
| | 0.193 | 0.003 | 0.031 | 0.005 | 0.029 | 0.066 | 0.002 | 0.010 | **0.001** | 0.001 | 0.023 | **EFN** |
| | | 0.004 | 0.007 | 0.022 | 0.038 | 0.098 | 0.082 | 0.020 | **0.001** | 0.010 | 0.079 | **EFS** |
| | | | 0.045 | 0.082 | 0.004 | 0.156 | **0.001** | **0.001** | **0.001** | 0.005 | 0.074 | **D** |
| | | | | 0.055 | 0.026 | 0.282 | 0.025 | 0.008 | **0.001** | 0.044 | 0.239 | **C** |
| | | | | | 0.047 | 0.435 | 0.065 | 0.012 | **0.001** | 0.068 | 0.301 | **I** |
| | | | | | | 0.435 | 0.422 | 0.374 | **0.001** | 0.289 | 0.430 | **J** |
| | | | | | | | 0.450 | 0.412 | 0.002 | 0.424 | 0.409 | **K** |
| | | | | | | | | 0.138 | **0.001** | 0.127 | 0.288 | **MG** |
| | | | | | | | | | **0.001** | 0.023 | 0.085 | **MGS** |
| | | | | | | | | | | **0.001** | **0.001** | **MGSaddle** |
| | | | | | | | | | | | 0.422 | **WC** |

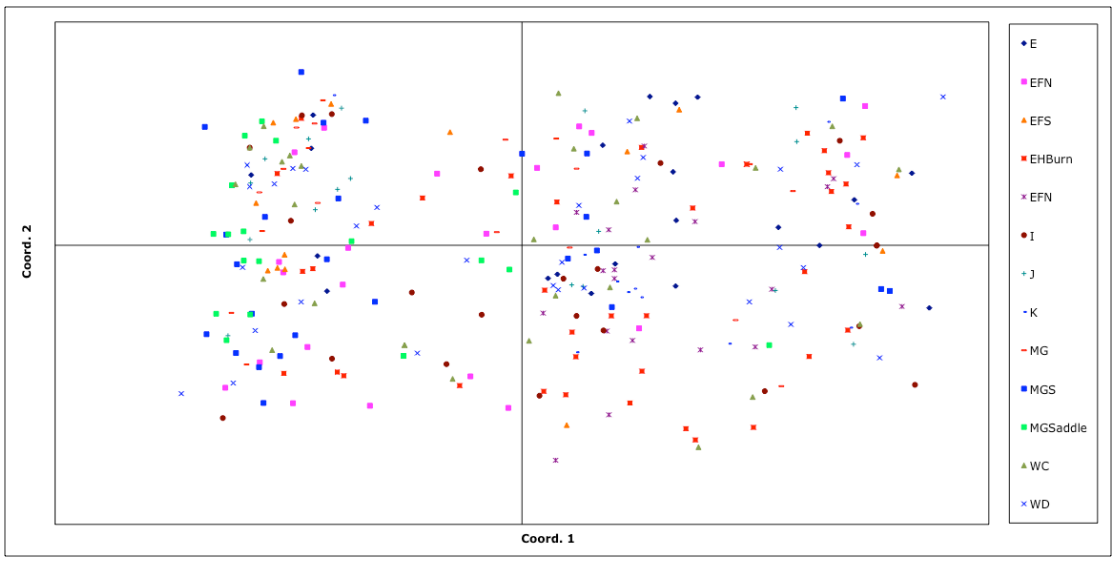



**Figure 8.** Principle coordinates analysis of samples from 13 populations of *Lepidosperma gibsonii*. Population codes as for the map in Figure 7. In this figure, samples placed close together are more closely related. The figure shows no strong clustering of individuals within populations; formal statistical tests demonstrated that only a few pairwise population comparisons are statistically distinct, with no geographic pattern.

*Population genetic diversity and comparison with other species*

Observed and expected heterozygosity, and fixation Index was estimated for all sampled *L. gibsonii* populations (Table 4). All were very similar in levels of diversity (Unbiased Heterozygosity estimates vary between 0.507-0.759). Fixation index for the species was 0.175 ± 0.026, suggesting a low but significant level of inbreeding.

In order to have a baseline comparison for the level of genetic diversity in L. gibsonii, several populations belonging to the *Lepidosperma costale* complex were sampled. A total of 88 plants from four populations of the *L. costale* complex were obtained, and confirmed as diploid in order to allow comparison of microsatellite data (tetraploids, with double the normal DNA content, are difficult to compare with diploid species, since they have four rather than 2 alleles per locus; in addition, tetraploid *Lepidosperma* have been shown to reproduce partly or wholly by agamospermy, and so show very different mating patterns to diploid populations). Several measures of heterozygosity and fixation index are reported in (Table 3). Genetic diversity within and between these populations/species is comparable with that observed in populations of *L. gibsonii*. Since sampled populations of both L. gibsonii and *L. costale* sens. lat. were sometimes quite small (e.g. populations EFN and Beanthiny Hill, where the c. 25 sampled plants represent most or a significant portion of the entire population), it is surprising that there is not greater

evidence of inbreeding and population bottlenecks, suggesting either that gene flow is high over the scale of these population (quite possible given the wind-dispersed pollen), or that the current small populations are relicts of past populations, and their observed diversity is due to persistence of plants dating from a period of greater population size.

**Table 5.** Average genetic diversity within sampled populations of *Darwinia masonii*, *D. purpurea* and *D. sp.* Chiddarcooping.

| Population | Ho | He | UHe | F |
|---|---|---|---|---|
| ***Lepidosperma gibsonii* populations** | | | | |
| **E** | 0.547 ± 0.076 | 0.713 ± 0.043 | 0.731 ± 0.045 | 0.240 ± 0.079 |
| **EFN** | 0.590 ± 0.082 | 0.621 ± 0.070 | 0.635 ± 0.072 | 0.044 ± 0.072 |
| **EFS** | 0.535 ± 0.113 | 0.649 ± 0.045 | 0.673 ± 0.046 | 0.182 ± 0.163 |
| **D** | 0.528 ± 0.080 | 0.692 ± 0.038 | 0.701 ± 0.038 | 0.242 ± 0.090 |
| **C** | 0.541 ± 0.085 | 0.652 ± 0.058 | 0.668 ± 0.060 | 0.170 ± 0.095 |
| **I** | 0.638 ± 0.083 | 0.733 ± 0.033 | 0.749 ± 0.033 | 0.135 ± 0.096 |
| **J** | 0.583 ± 0.090 | 0.638 ± 0.052 | 0.657 ± 0.053 | 0.108 ± 0.097 |
| **K** | 0.625 ± 0.100 | 0.727 ± 0.039 | 0.759 ± 0.041 | 0.149 ± 0.116 |
| **MG** | 0.587 ± 0.090 | 0.643 ± 0.058 | 0.660 ± 0.059 | 0.102 ± 0.102 |
| **MGS** | 0.501 ± 0.085 | 0.642 ± 0.068 | 0.655 ± 0.069 | 0.244 ± 0.088 |
| **MGSaddle** | 0.407 ± 0.072 | 0.493 ± 0.076 | 0.507 ± 0.079 | 0.185 ± 0.034 |
| **WC** | 0.542 ± 0.069 | 0.688 ± 0.024 | 0.701 ± 0.025 | 0.212 ± 0.096 |
| **WD** | 0.508 ± 0.072 | 0.684 ± 0.037 | 0.696 ± 0.037 | 0.261 ± 0.098 |
| ***Total*** | *0.549 ± 0.022* | *0.660 ± 0.014* | *0.676 ± 0.015* | *0.175 ± 0.026* |
| ***Lepidosperma costale* complex** | | | | |
| **Blue Hills 1** | 0.454 ± 0.117 | 0.565 ± 0.098 | 0.576 ± 0.100 | 0.243 ± 0.114 |
| **Blue Hills 2** | 0.548 ± 0.159 | 0.626 ± 0.112 | 0.640 ± 0.114 | 0.088 ± 0.173 |
| **Beanthiny Hill** | 0.595 ± 0.107 | 0.699 ± 0.040 | 0.715 ± 0.041 | 0.176 ± 0.109 |
| **Wanara Rd** | 0.535 ± 0.134 | 0.609 ± 0.096 | 0.638 ± 0.101 | 0.239 ± 0.180 |

### *Clonality*

Clumps of *L. gibsonii* are not necessarily a single genetic individual. The density of seedlings as reported elsewhere in this document raises the possibility of coalescence and intermingling of individuals as they clonally spread laterally by rhizomes. In order to determine the extent of clump coalescence, and the effect on census vs actual population size, a total of 213 samples were taken from 39 clumps of random sizes (excluding very small clumps clearly composed of ramets from a single individual), from 3 separate populations and genotyped using the microsatellite loci described above.

**Results:** A total of 49 individuals were detected amongst the 39 clumps, assuming correct assignment of individuals (which seems likely, as all 'individuals' recognised had at least 2 differences from other genotypes). Each clump was composed of between 1-3 individuals, with an average 1.25 individuals per clump.

**Conclusions:** The current population census of *Lepidosperma gibsonii* is approximately 1.25 times greater than currently estimated, assuming the observed ratio of intermingled clumps is similar in unsampled populations. Any investigations requiring complete mapping of individuals (e.g. mating studies) requires exhaustive genetic sampling within clumps to identify all individuals.

Partial clump death, after fire or drought, which has been observed in some individuals, may kill one or more genetic individuals, without complete death of the 'clump'. It is therefore likely that *Lepidosperma* death rates from fire and drought are underestimates (by 0-25%), since even a single resprouting ramet (and therefore a single individual) may be scored as survival of the clump, overlooking potential death of co-habiting individuals.

**Summary and recommendations**

- The increased population sampling (due to the discovery of more populations of *L. gibsonii* since the preliminary study) largely agrees with the preliminary results, although a slightly higher level of genetic population structure was observed (94% variation within populations vs 985 variation within populations).

- While there is little genetic structuring between populations of *L. gibsonii*, pairwise tests show that some populations are statistically supported as non-randomly mating with other populations. This suggests that there are some barriers to complete gene flow across the Mt Gibson range system, and that the precautionary principle should apply to avoid mixing genotypes between populations without careful consideration of consequences.

- The current population size of *L. gibsonii* is estimated to be 1.25 times greater than the current census, due to multiple genetic individuals within some clumps.

- Some measures of survival (e.g. from fire or drought) could be over-estimates by up to 25% due to unobserved loss of multiple genetic individuals from compound clumps.

- Any investigations requiring complete mapping of individuals (e.g. mating studies) requires exhaustive genetic sampling within clumps to identify all individuals.

### 4.1c Monitoring genetic threats

Baseline data on levels of genetic diversity within populations, relatedness among populations, the extent of inbreeding observed in populations, the processes contributing to inbreeding and the fitness costs of inbreeding was obtained and is described in sections **4.1b** and **4.3e**. These results do not indicate any level of inbreeding depression due to past bottlenecks. This data can be compared to future population (e.g. following translocation, regeneration after fire or catastrophic events) to detect departures from "normal" processes, e.g. pollinator effectiveness in reduced or translocated populations, or lowered outcrossing rate in small, isolated populations.

## 4.2 POPULATION DEMOGRAPHY

The demography of populations of *D. masonii* and *L. gibsonii* was studied by monitoring tagged plants in permanently marked plots. The initial tagging and measuring of plants for survey commenced in June/July 2007 and surveys were repeated in subsequent winters. Four extra plots were added in May 2009 within the boundary of a small experimental fire (12 May 2009) at the northern end of Extension Hill South. New seedlings observed in plots over the course of monitoring were mapped, tagged and measured in the same way as other plants. In each plot, plants were labelled with uniquely numbered aluminium tags and mapped to 1-5cm accuracy within an x-y system in each plot. Site factor data associated with plots was also recorded: GPS locality, estimated slope and aspect (later confirmed from GIS - DEM derived maps), estimated fire age (later confirmed from air photo analysis), landscape position (gully, ridge, slope..), mean vegetation height, community composition, estimated vegetation cover (subsequently confirmed by hemispheric photo image analysis), surface % cover of litter, rock, gravel, bare ground, soil crusts (lichen, algae, mosses). Soil samples were also collected for chemical analysis tests, performed at the WA Chem Lab, included electrical conductivity, pH, % organic Carbon, total N and 18 other major elements (of which, Mo, Cd, Se and As concentrations were at or below the limit of reporting and are therefore not presented)

Survey plots were located at six principal locations; both species were surveyed on Mt Gibson, Iron Hill and Extension Hill South, while plots for *Lepidosperma gibsonii* were additionally located at Iron Hill North and close to the Emu Fence (on duricrust; the only non-BIF locality surveyed) and three *D. masonii* plots were placed on Mt Gibson South (Figure 11).

The June/July census date was initiated to commence data collection soon after project startup and to enable 3 years of data collection within the project

period, running from May 2007 to June 2010. In addition to the midwinter demography survey this program necessitated an early summer survey for seed production. However, as winter is the main growing season, a census in winter is not ideal as it means each census period, while incorporating one full summer, includes parts of two different winter growing periods. It is suggested that for future monitoring, the census date is moved to late spring. This would clarify the interpretation of the census year (to include all of one growth season not halves of two) and to reduce field survey effort (by combining seed and demography surveys). Three midwinter censuses have been completed from 2007, and the 2101 census is proposed for early summer.

**Fire history**

A fire history map was constructed for the region from air photo runs from 1968, 1974, 1990, 1996, 2000 and 2005. These were of varying scales, but mostly of high quality. Also utilised, were medium-low resolution satellite images from 1965-67, 1972, 1989, 2000 and 2004 and the high quality recent imagery from Google Earth (http://earth.google.com/). Other sources of fire history data used include Sentinel (MODIS hotpot data from Geosciences Australia, from 2003; http://sentinel.ga.gov.au), DEC preliminary fire mapping (1970-2005 – based on Landsat imagery), Landgate (from 1997: http://firewatch.landgate.wa.gov.au/), as well as personal observations of various workers, notes from literature and photographs. Each of these sources fails in at least one respect be either not recording all fires, accurately mapping boundaries or correctly identifying fire dates.

While these sources do not always agree, the best model of fire history since the mid 1960's (Figure 10) describes just four major fires on the Mt Gibson range and several others nearby. Scars for the two recent fires are clearly visible on images dating from 2004 and 2005, and these can be accurately dated from Sentinel to 7-10$^{th}$ February 2003 and from personal communications to December 2005. The two previous fires are attributed to 1972 and 1969 are visible on high resolution images up to the present, and dating back to 1972. Evidence supporting the dates of these fires include their absence from the 1968 photo, presence in 1972 and relative freshness apparent in the two fire scars in the 1972 and 1974 images (Figure 9). While it is recognised that this dating may be imprecise, variation of a year or two is relatively insignificant relative to the subsequent 40 years of growth of plants subsequently. In fact only one of these fires appears to have burnt surveyed populations of *D. masonii* or *L. gibsonii*, although the 1972 fire may have burnt populations of *L. gibsonii* to the west of the Mt Gibson range.

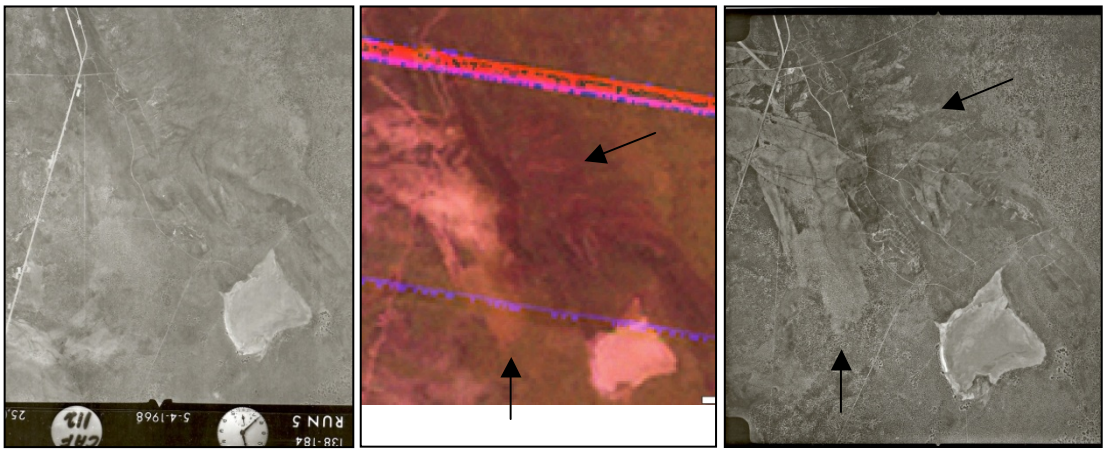


**Figure 9.** Air photo images from April 1968 (left) and December 1974 (right) with a LandSat image from 1972 (middle). Major identifiable features include the salt playa to the south of Mt Gibson in the bottom right of each image, the Great Northern Highway in the west, with the airstrip, built between 1968 and 1972 in the north west. No nearby fire scars are apparent on the 1962 image, but two are apparent on both the 1972 image: the '1972' fire is indicated by the lower arrow, and the '1969' fire scar by the upper arrow). The outlines of both fires are clearer in the 1974 image, with the '1972' fire most apparent.

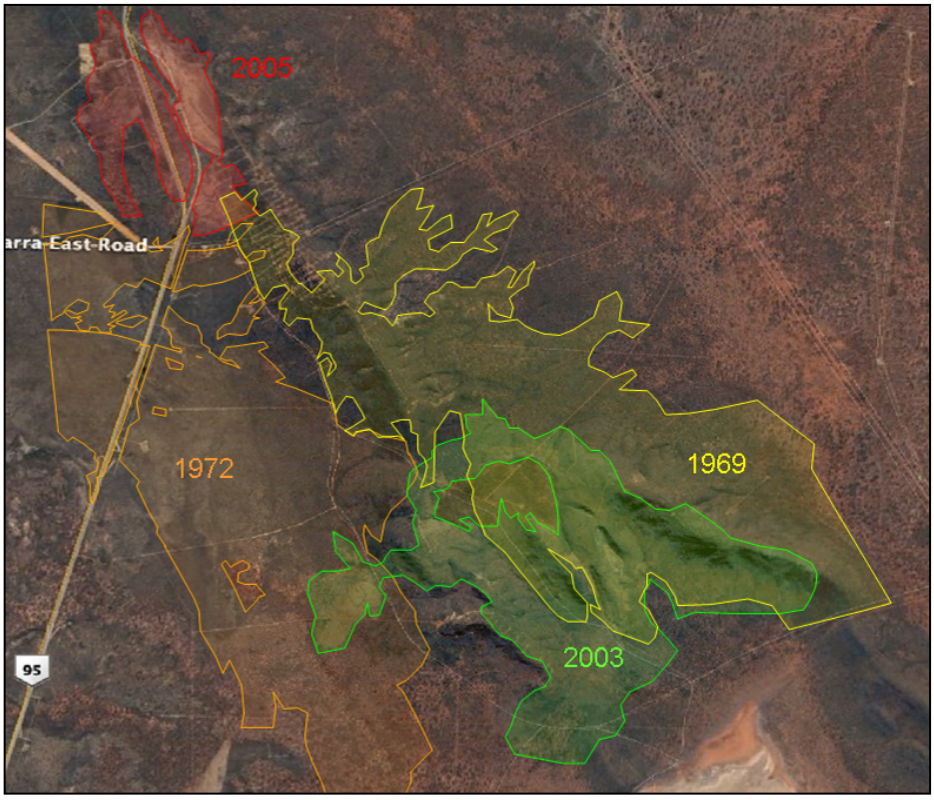



**Figure 10.** Mt Gibson-Extension Hill fire history; 1968-2010

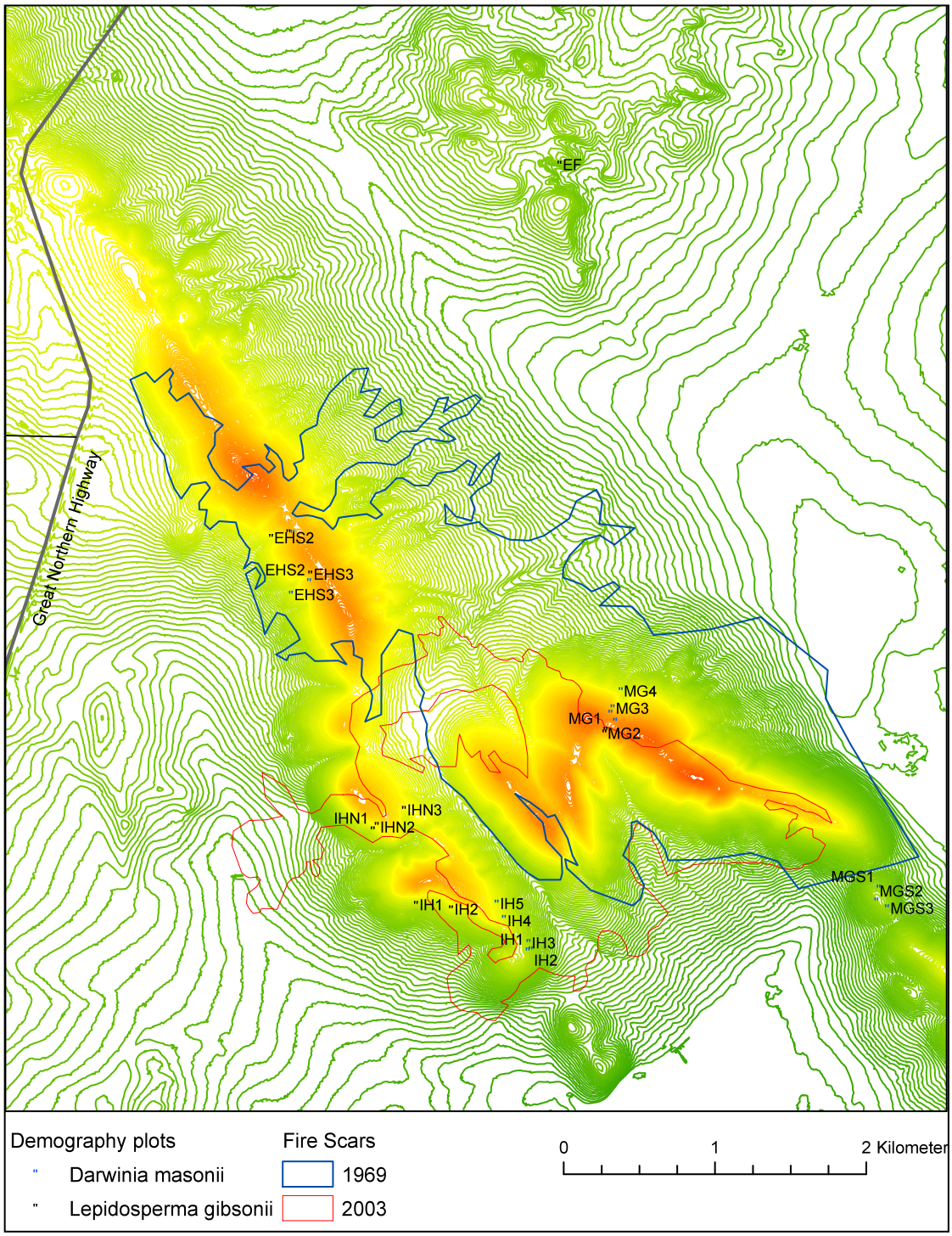



**Figure 11** Location of permanent population demography monitoring plots in relation to fire history and topography (contours at 1m intervals).

Thus, fires on the Mt Gibson range fall into two periods, 'recent' (2003/2005), when the north of Extension Hill and the South West part of the range burnt, and older (1969/1972), when the central and western parts of the range burnt. As a result, most of the range was last burnt either 2 or 5 years prior to the project's start in 2007, or ~35-40 years prior, or long unburnt (parts of

Extension Hill and Iron Hill). As there is little overlap in fire scars, fire interval cannot be calculated for most of the range: the main exception is for a region between Mt Gibson and Iron Hill East which burnt in 2003 after an interval of ~ 34 years. All other areas have had fire intervals of not less than 42-35 years, but as no scars are visible on the 1968 image, and with a conservative estimate of the period for which scars are visible, this minimum previous interval estimate is more likely >50 years. Evidence from demographic studies (below) suggest a much longer period.

Some important issues in this fire history analysis must be noted. Firstly, the map focuses on the range itself and there is some uncertainty at the range's extremities, with evidence that some of the mapped fires may have extended to areas of Mt Gibson South and Extension Hill North that are not fully mapped. Some smaller areas within mapped fire boundaries are known or suspected to have not burnt. Finally, notes from various workers in the mid 1990s report inference of fires from the previous 1 – 10 years, but these inferences are not borne out in the 1996 (or subsequent) air photo series. These notes derive from observations of the state of development of vegetation, which our own experience reveals to be misleading – our initial fire age estimates were proven to underestimate fire dates by as much as 50%.Demographic results are described in terms of the fire histories as indicated in Figure 11. The fire history of the Emu Fence and Mt Gibson South plots is unknown, but presumably these sites are long unburnt. Similarly the *L. gibsonii* plots on Iron Hill are not known to have burnt since the late 1960s at the earliest (the LIH2 plot is located in a small, clearly unburnt patch embedded in the 2003 fire). These sites are described as 'old', or 'long-unburnt'.

All Extension Hill South and Mt Gibson plots occur within the 1969 fire boundary, but two of these – *D. masonii* DMG2 and DMG3 – have a population structure, including very large stem sizes, which are taken to indicate that these rocky and open sites did not burn in that fire. As well as burning in the 1969 fire, the two Mt Gibson *L. gibsonii* plots were additionally burnt in 2003. The five remaining *D. masonii* and three *L. gibsonii* sites (Iron Hill and Iron Hill North) were also all burnt in the 2003 fire and were therefore 4 years old at the time of their first survey (into their fifth growing season).

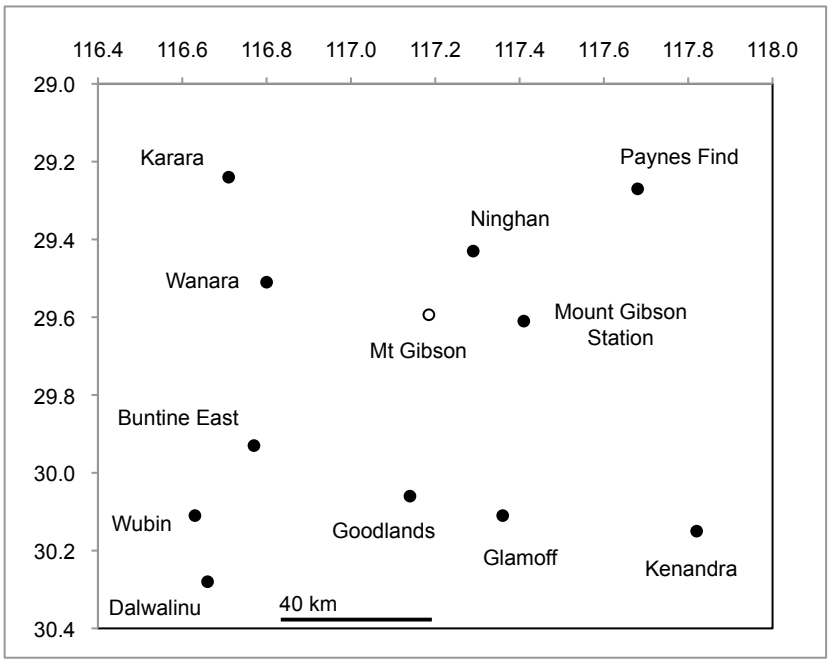
The two oldest fire ages (i.e. 1969 and <1968) are collectively described as 'older' or 'mature' sites, while the 2003 fire sites may be described as 'young' or (in the case of *D. masonii*, 'seedling') sites.

**Climate history**

Climate data (chiefly rainfall) exists for several weather stations in the region of the Extension Hill – Mt Gibson Range (Figure 12a). Several stations have very long records (e.g. Ninghan, to 1905), others have opened and closed at different times, and many have missing data for various periods (e.g. Ninghan in 1909, 1968, 1971 and 1972). One rainfall record operated between 1970 and 1972 at 'Mt Gibson', possibly at Iron Hill while the adit there was being worked. The closest operating rainfall records are from Ninghan Station, while Mt Gibson Station (distinct from 'Mt Gibson') records missed parts of 2009 and 2010. In 2009, BGPA purchased and installed an automated climate station near the summit of Mt Gibson close to monitored populations of *D. masonii* and *L. gibsonii*. The closest current (non-BOM) records are from the Mt Gibson gold mine camp, which indicate a mean of 240 mm in the decade from 1999. Regionally, rainfall averages between 350 mm (at Dalwallinu) and 284 mm (Paynes Find) - (Figure 12b).

Regional rainfall over the study period (Figure 13) included two years of average to above average rainfall (2008 and 2009) and two below average years (2007 and 2010). While 2010 still has some months remaining, rainfall totals to October are, for a number of nearby stations, amongst the lowest on record. By October 2010, BGPA's Mt Gibson weather station had recorded <100 mm since January, < 50% of the regional annual average. The study was preceded by four years of approximately average rainfall.

While the exact date of fire events around 1969 are not certain, it may be worth noting rainfall over the period 1967-1971 during which the fire and the post-fire population regeneration is likely to have occurred. Regional rainfall over these years was average, high, very low (1969 was the driest recorded year for 4 of the 6 then-active stations), above average, and average respectively. Thus, if fires did occur in 1969, they occurred during a period of severe drought and were followed by several years with good growing conditions.



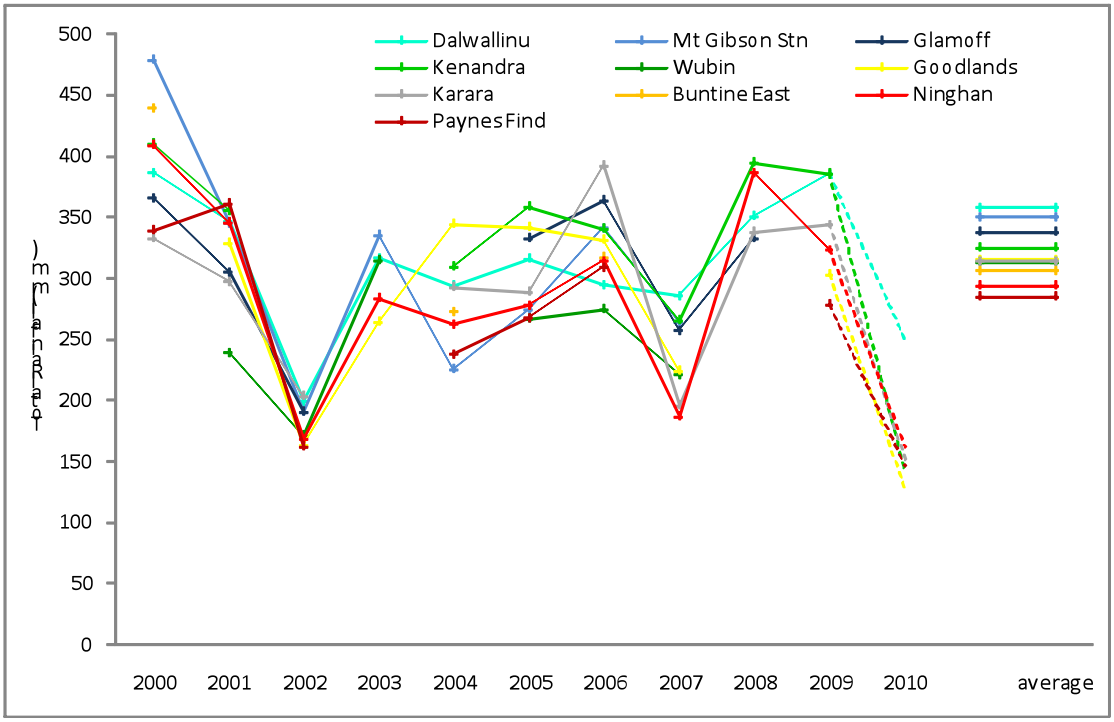




**Figure 12 a)** Locality of climate stations relative to BGPA's Mount Gibson climate station (open diamond). **b)** Annual rainfall for 2000 to 2009, to October 2010 (dashed) and for the long term average for nearby rainfall/climate stations (www.bom.gov.au).

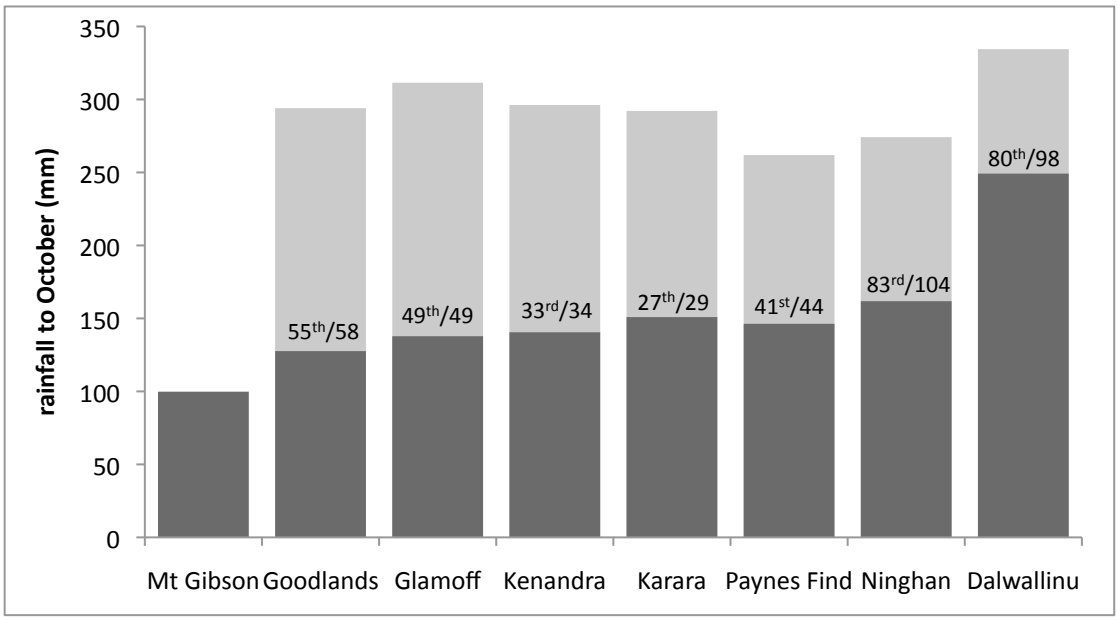



**Figure 13** Cumulative rainfall to October, for 2010 (dark bars) and the long-term average (light bars) for the BGPA climate station on Mt Gibson (average not known), and for nearby stations with complete records (www.bom.gov.au). The rank of the 2010 record relative to the size of the record (number of years complete to October) also given. On average, rainfall to October accounts for 89% of annual rainfall for these stations.

### *Darwinia masonii*

*Darwinia masonii* populations were monitored in 15 10×10 m plots on Extension Hill, Iron Hill, Mt Gibson and Mt Gibson South, with sites last burnt in 2003, 1969, or some time prior to 1968 (Figure 11, Table 6). In each plot, all live plants, including seedlings, were tagged, mapped and measured. Plots had between 13 and 57 plants each, and a total of 378 plants were measured. Stem density varied between 0.13 and 0.57 plants.$m^{-2}$ and averaged 0.25 plants.$m^{-2}$. Plots were established in July 2007 and remeasured annually.

**Table 6** Midpoints and fire histories of the *Darwinia masonii* 10×10m demographic survey plots.

| Plot | Population | LAT | LONG | Last burnt |
|---|---|---|---|---|
| DEHS1 | Extension Hill South | 29°34.953 | 117°09.940 | 1969 |
| DEHS2 | Extension Hill South | 29°35.124 | 117°09.999 | 1969 |
| DEHS3 | Extension Hill South | 29°35.169 | 117°09.934 | 1969 |
| DIS1 | Iron Hill south | 29°36.437 | 117°10.779 | 2003 |
| DIS2 | Iron Hill south | 29°36.433 | 117°10.789 | 2003 |
| DIS3 | Iron Hill south | 29°36.407 | 117°10.781 | 2003 |
| DIS4 | Iron Hill south | 29°36.321 | 117°10.694 | 2003 |
| DIS5 | Iron Hill south | 29°36.267 | 117°10.668 | 2003 |
| DMG1 | Mt Gibson | 29°35.621 | 117°11.090 | 1969 |
| DMG2 | Mt Gibson | 29°35.592 | 117°11.073 | Older |
| DMG3 | Mt Gibson | 29°35.573 | 117°11.081 | Older |
| DMG4 | Mt Gibson | 29°35.512 | 117°11.110 | 1969 |
| DMGS1 | Mt Gibson South | 29°36.214 | 117°12.030 | Older |
| DMGS2 | Mt Gibson South | 29°36.259 | 117°12.022 | Older |
| DMGS3 | Mt Gibson South | 29°36.284 | 117°12.060 | Older |

For all tagged *D. masonii* plants in each plot height was measured as the vertical distance from the highest living tissue in the canopy to level at which the stem emerges from the ground. However, as plants were occasionally prostrate or reclining, and many grew on slopes, this measure often did not adequately describe plant size. In these cases, the equivalent 'length' was recorded as distance from the base of the stem on the ground, to the furthest edge of the canopy. 'Canopy diameter' was also measured for all plants as the longest horizontal distance across the canopy, and secondly ('diameter 2') as the horizontal distance across the canopy in the direction orthogonal to the first. Stem basal diameter also was measured in initial surveys for all plants. This was measured, using digital callipers, as the diameter of the stem and bark close to the plant base, but above any immediate swellings or corky

areas. For non cylindrical stems, this was recorded in two horizontal dimension following the same principals as per canopy diameter measurements. Inflorescence numbers were counted, and a subjective 'health' score using a 5 point scale (Table 7) was also given for all plants. The health score was determined on the basis of relative foliage colour (noting that colour changes through the year – see **4.5e Plant Health**) and on inspection of vegetative bud activity.

**Table 7** Qualitative health score for *Darwinia masonii*.

| Score | Plant vigour | Canopy | Leaf colour | New growth |
|---|---|---|---|---|
| 0) Near death | Dead or nearly | Absent or nearly | Yellow/ brown | absent |
| 1) Very poor | Very low | Thin | Yellow / brown | absent |
| 2) Poor | Moderate | Moderate-full | Grey - green some yellow-brown | absent |
| 3) Fine | Good | Full | Blue green | present |
| 4) Very good | Precocious seedling reproduction | Full | Dark green | vigorous |

The slow, irregular and modular growth form of *D. masonii* means that neither plant height nor canopy diameter is ideal for measuring the 'growth' of mature plants at the year-to-year scale. In any year, branchlets at the top or furthest extent of a plant's canopy may die-back, while at the same time, strongly growing branchlets not at the canopy extremes would not contribute to an increase in measured plant size. Basal stem diameter may be a preferable measure of plant growth, but as plants (older ones particularly) have irregularly shaped stems – which may often crack, split or swell or lose or gain spongy bark – this measure also proved not ideal. However, seedling growth forms are more regular and their increase in height and diameter is also more amenable to meaningful measurement. As a result, data on plant population structures and growth rates are presented in a number of metrics.

*Population structure*

When surveyed in 2007, plant size ranged up to 240cm in height and 2.5m in canopy width and stem basal diameters varied from 1 to 74 mm.

Plant size varied in a clear pattern with population age (time since last fire) but stem densities did not (Table 8). The frequency distribution of plant size in plots (Figure 14, Figure 15) includes distinct peaks and narrow size ranges in

the 2003 and 1969 plots and broader and flatter distributions in older sites. These patterns indicate that plants are killed in fire, and that the majority of plants arise in a single cohort following fire. Older site size distributions suggest that a small number of seedlings may recruit at infrequent intervals in the absence of fire.

**Table 8.** Attributes of *Darwinia masonii* populations and plants assessed in sites last burnt at in 2003, 1969, and prior to 1968 as assessed in 2007.

| | | Year last burnt | | |
|---|---|---|---|---|
| | | 2003 | 1969 | <1968 |
| Sites (n) | | 5 | 5 | 5 |
| Age (years at 2007) | | 4 | 38 | >40 |
| N | | 128 | 149 | 100 |
| Density (stems.m$^{-2}$) | | 26 | 30 | 20 |
| Height 2007 (cm) | Min-Max | 11-72 | 36-202 | 26-240 |
| | Mean | 37 | 110 | 119 |
| Corresponding growth rate | (cm.yr$^{-1}$) | 9 | 2.9 | |
| Canopy diameter 2007 (cm) | Mean | 15 | 59 | 110 |
| Corresponding growth rate | (cm.yr$^{-1}$) | 3.8 | 1.5 | |
| Extrapolated age | years) | | | 73 |
| Stem diameter 2007 (mm) | Min-Max | 1.1-9.2 | 2.9-37 | 2.1-120 |
| | Mean | 3.8 | 15 | 33 |
| Corresponding growth rate | (mm.yr$^{-1}$) | 0.95 | 0.39 | |
| Extrapolated age | (years) | | | 85 |

Plants growing in sites burnt in 2003 (i.e. 4 year old seedlings), averaged 37cm in height, 15 cm in diameter and 3.8 mm in stem diameter when measured in 2007 (Table 8). These sizes represent mean growth rates of approximately 9 cm.yr$^{-1}$ in height, 4 cm.yr$^{-1}$ in diameter and 1 mm.yr$^{-1}$ in stem diameter over their 4-year lifetimes. These growth rates are between 2 and 4 times greater than those observed in the next two years of survey (below), suggesting considerable year-to-year variation in growth rates.

Extrapolating the mean growth rates for canopy diameter and stem diameter from plants in sites last burnt in 1969 to the average dimensions of the older sites, suggests a mean ages of plants in these older sites of 73 and 85 years respectively. As well as assuming that the assessed mean canopy and stem diameters and their growth rates for this period are correct, representative and unvarying through time, this calculation assumes that all of the older plots were all burnt in the same previous fire, and that all plants date from the last fire. These assumptions suggest that the estimated age of these older populations 73-85 years may be underestimate their actual age. Taking the value of 85 years suggests a fire in these areas in 1922 (with 162 mm, 1922 was the 8$^{th}$ driest year on record at Ninghan, 1924 was almost identical).

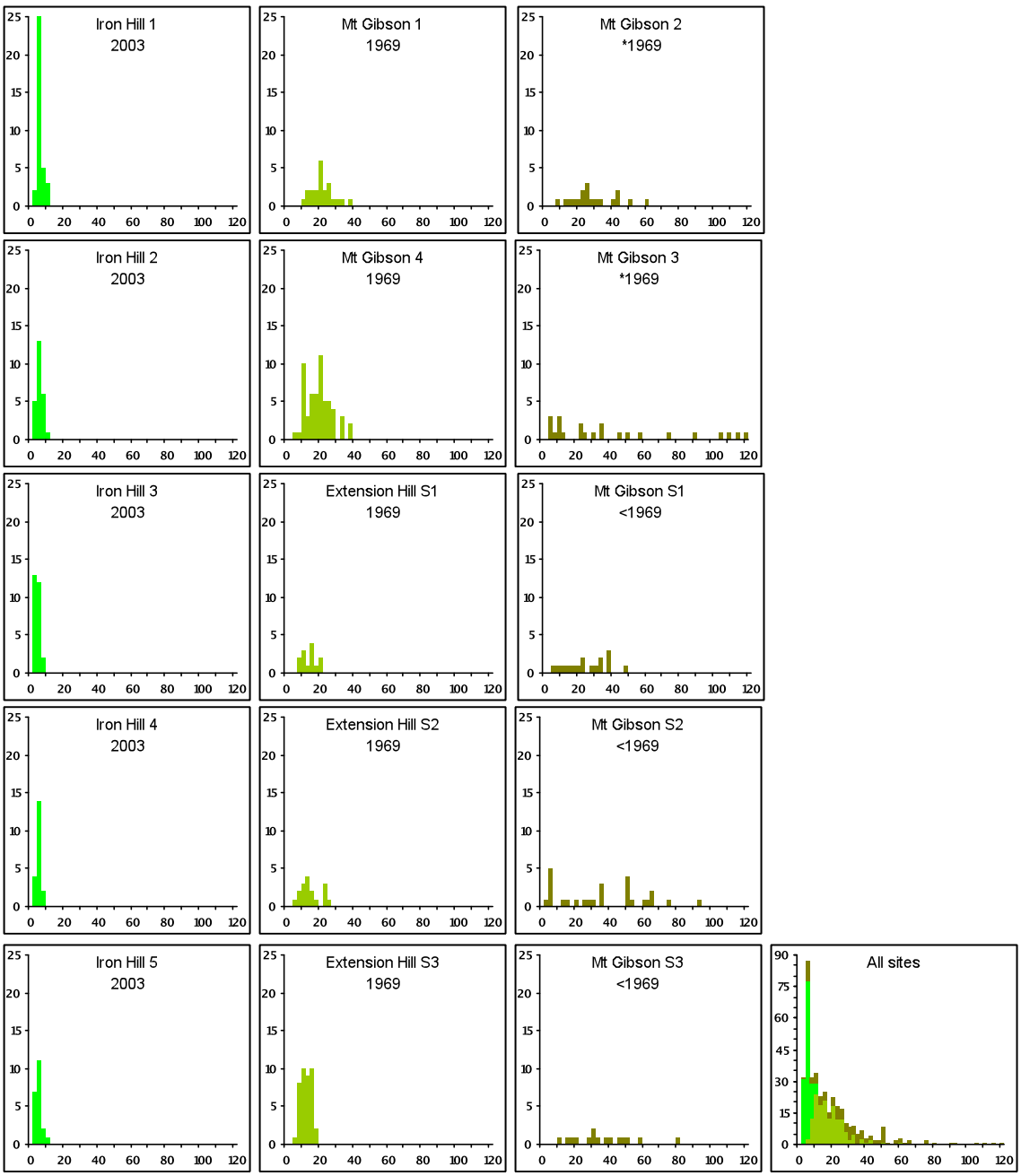



**Figure 14.** *Darwinia masonii* population structure: number of plants (Y-axis) classified by size (X-axis: Stem diameter close to ground level, 2.5 cm increments). Data from 2007 survey of fifteen 10×10m plots. Colour codes correspond to date of last fire (2003, 1969, <1969; *1969 = within the 1969 boundary but appears to have escaped that fire and hence is also <1969)

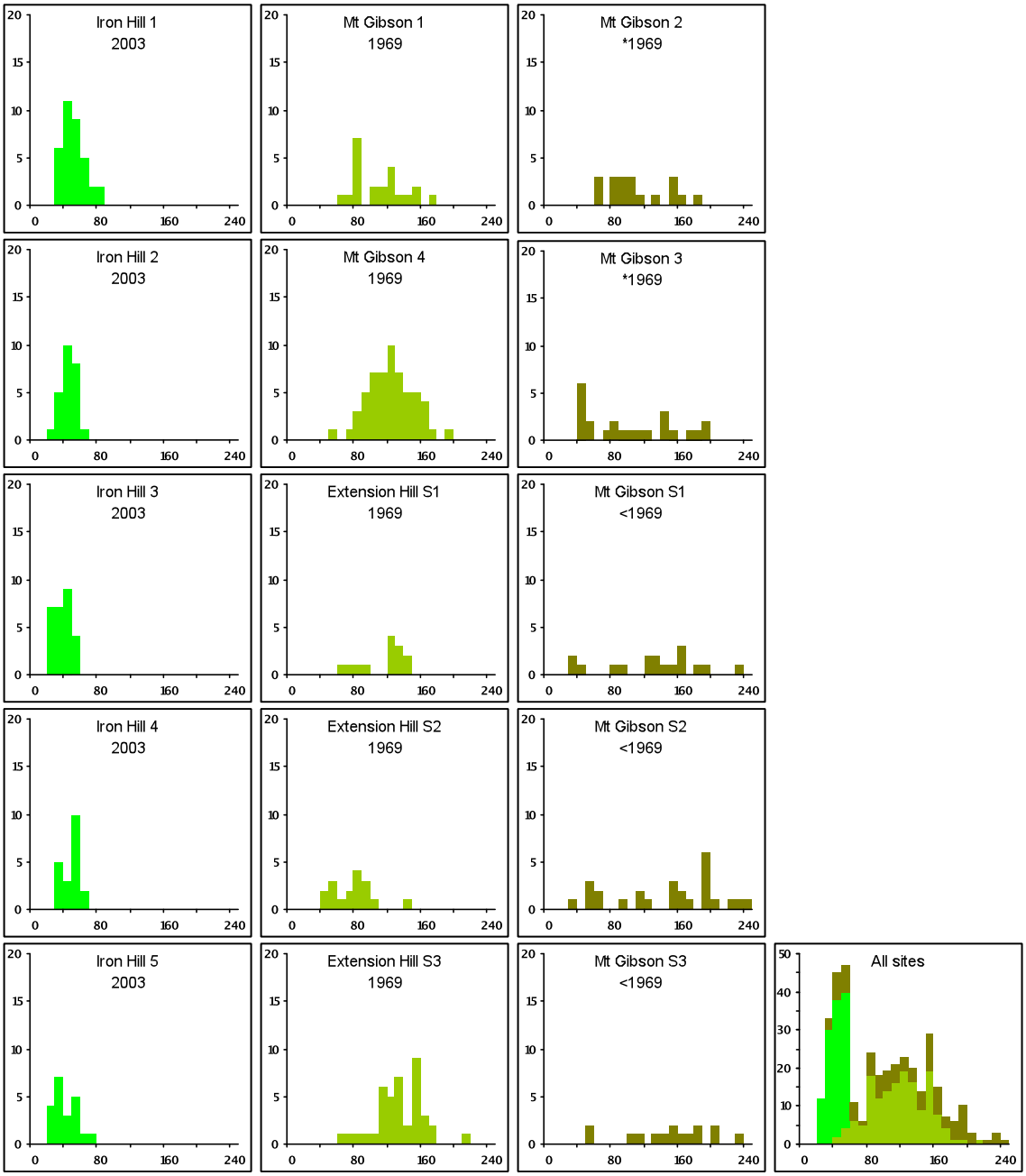



**Figure 15.** *Darwinia masonii* population structure: number of *Darwinia masonii* plants (Y-axis) classified by size (X-axis: plant height in 10 cm increments). Data from 2007 survey of fifteen 10 × 10m plots. Colour codes correspond to date of last fire (2003, 1969, <1969; *1969 = within the 1969 boundary but appears to have escaped that fire and hence is also <1969)

### *Recruitment*

Just one new seedling was found in the 15 unburnt survey plots over the course of the study, this in July 2009 at the Mt Gibson South plot 2, a long unburnt site. The seedling was 9 cm tall, suggesting that it may have germinated in the previous winter (the preceding survey was July 2008). For what it is worth, this represents a mean interfire recruitment rate of 0.0023 new seedlings per adult per year in older plots.

In contrast, 233 seedlings were counted in the four plots (total area = 250 $m^2$) surveyed following the May 2009 experimental fire. This indicates a mean density of *D. masonii* seedlings of 0.9 $m^{-2}$. There were 93 pre-fire adults in the same area – equivalent to 0.37 $m^{-2}$ and 1.2-1.9 times the density of adults in the unburnt survey plots. This would represent an average seedling production rate of 2.5 seedlings per pre-fire adult. However, the experimental fire was patchy and did not burn the entirety of the four plots, such that 20 (22%) of the 93 pre-fire adults did not burn. If we use this same proportion to represent the area of plots that did not burn, and assume that seedlings only germinated in burnt areas, it may be more appropriate to record a seedling density of 1.2 seedlings.$m^{-2}$ of burnt area and 3.2 seedlings per adult.

*Survival / Mortality*

Of the 277 seedlings tagged at the end of the winter following the May 2009 experimental fire, just 9% were refound and alive one year later in October 2010. In addition, 79% were refound and dead, and 11% could not be found. Thus mortality rates of *D. masonii* seedlings over their 1$^{st}$ summer was 88-91%. 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.

Three of the 373 *D. masonii* plants tagged in demography plots in July 2007 died over the following 12 months: all were seedlings, and two were from one plot (Iron Hill South 5: DIHS5). A further 14 seedlings from this plot died over the following 12 months as did two smaller individuals (53 and 62 cm tall) from long unburnt populations on Mt Gibson and Mt Gibson South. The 5 remaining DIHS5 seedlings were still alive in November 2009, but a further 16 seedlings from other 2003-fire area plots had died. These deaths indicate a mean seedling mortality rate of 9.8% per year over the study period (Table 9), but also significant spatial and temporal variation in seedling survival (Figure 16).

**Table 9** Number and proportion of tagged *Darwinia masonii* plants dying in each year 2007-2010; comparing seedlings from 2003 fire and older plots.

| | 2003 seedlings | | 1969 + older | |
|---|---|---|---|---|
| | N | % | N | % |
| 2007-2008 | 3 | 2.5 | 0 | |
| 2008-2009 | 14 | 11.7 | 2 | 1.6 |
| 2009-2010 | 16 | 15.2 | 0 | |
| average | 33 | 9.8 | 2 | 0.5 |

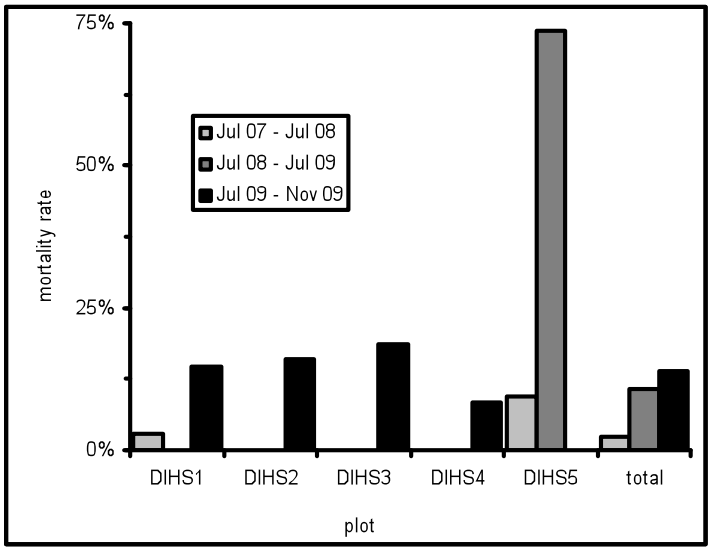



**Figure 16** Proportion of *D. masonii* plants dying in five Iron Hill South seedling plots (burnt Feb 2003) at three sample times (the last not representing a full year).

The 16 deaths in DIHS5 represent a major population collapse for this locality over the two years to July 2009: in one year, 74% of remaining plants died. Skeletons of a further 21 seedlings were counted at the establishment of the plot, suggesting that poor survival is endemic at the site. It is unclear what the cause of this death is at this and other 2003 plots. The DIHS5 plot is the hottest of the five seedling plots in terms of solar radiation receipt (with an aspect of 65° versus 73-86°) and among the steepest (10° versus 8-10°). It is also mapped as a distinct geology: undifferentiated “white rock” versus cavernous Limonite and Breccia “(only hematite debris cemented by limonitic material)”, although only a short distance down-slope from the mapped contact with these. These differences may well suggest important differences in soil water holding capacity and micro-climate. But the fact that *D. masonii* seedlings occur there at all suggests that a number of adult individuals must have survived and reproduced on the site or very nearby prior to the fire.

Whether the increase in mortality of seedlings in the remaining plots through spring of 2009 is an indication of the commencement of a similar period of mortality in the other sites remains to be seen.

With just two recorded deaths in the older plots, the mortality rate in these areas between 2007 and 2009 averaged 0.5% per year (Table 9). Tagged plants are yet to be resurveyed in 2010 at time of writing, but a sample of 261 plants adjoining plot DMGS1 on Mt Gibson South (last burnt <1969) and marked in the pollination study were re-surveyed. These plants had a population-wide mortality rate of 10.3%, much higher than that observed in previous years in survey plots. This mortality also seems likely attributable to

drought, but is of concern both for its magnitude with a significant impact on population sizes, and if projected climate change does lead to increased drying, or increased frequency of dry years in the region.

*Health scores*

Most (75-99%) of the plants in older sites had good health scores (i.e. scores of 3 or 4, Figure 17). Just one and two individuals had low health scores (0 or 1) in 2007 and 2008 respectively (i.e. ≤ 1%). Each of these three plants had recovered to a score of 3 by 2009. The proportion of plants with a poor health score (2) varied from 0-25%. The only two plants from these older sites that died in the survey period (both by July 2009) had scores of 2 and 3 in 2008, and 3 in 2007.

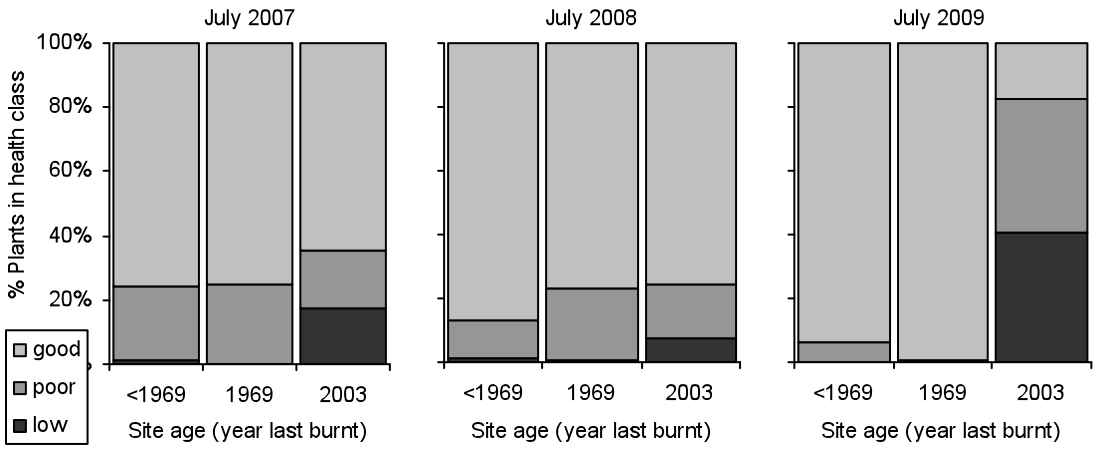



**Figure 17** Variation in health scores for tagged Darwinia masonii plants varying between years and site age.

Examining patterns of annual change in health (Table 10) indicates greater fluctuation of apparent health among seedlings than in adults. Three quarters of plants in older plots did not change health score (most were 3), 20% improved in their health score and 4% declined, and very few moved more than one score class. In contrast, seedlings maintaining a constant health score across years were in the minority (18 - 51%). 82% of seedlings declined in health (26% by two or more scores) or died in 2007-2008, while 25% improved and 24% declined or died in the following year.

Averaging across years, 0.3% of seedlings with good health scores (3 or 4) died within the next 12 months, 20% of those with poor health (2) died and, 11% of individual seedlings with very poor or worse scores (1 or 0) were dead within 12 months. The proportion of live seedlings with low health scores has fluctuated between years and was highest in July 2009, suggesting that greater mortality of seedlings may be expected subsequently.

**Table 10** Year to year variation in health status of *Darwinia masonii*

| Site age | older | | | 2003 | | |
|---|---|---|---|---|---|---|
| Period | 2007-2008 | 2008-2009 | 2007-2009 | 2007-2008 | 2008-2009 | 2007-2009 |
| improved | 19% | 14% | 21% | | 25% | 6% |
| >1 score | 1% | | 0.4% | | 3% | |
| 1 score | 18% | 14% | 20% | | 21% | 6% |
| no change | 76% | 75% | 75% | 18% | 51% | 19% |
| declined | 4% | 11% | 4% | 67% | 22% | 61% |
| 1 score | 3% | 11% | 3% | 40% | 22% | 31% |
| > 1 score | 0.5% | 0.4% | 0.4% | 26% | | 31% |
| died | 1% | | 1% | 15% | 2% | 14% |
| Total | 220 | 231 | 236 | 121 | 122 | 121 |

Live plants given a health score of 0 (near death) in 2007 mostly did eventually die, although all survived for more than one year before doing so (Figure 18). All but one of the 19 plants with a very poor health score (1) in 2007 were seedlings: four were dead by July 2008 and eight more (all seedlings) died by November 2009. Some of these plants regained health to a good standard within a year, but even so, some of these later died, and none had scores > 2 (poor) at last survey.

**Figure 18.** Two plants from plot DIHS4 photographed in July 2009. Both had experienced complete leaf loss and had health scores of 0, or 1 in the preceding two years, indicating that they had persisted with no canopy and only the leaf buds like those visible here on the stem for at least a few years. Their continued survival seems unlikely.

*Growth*

The growth of older plants appears to be slow relative to measurement errors and diffuse across their canopies – not necessarily resulting in an increase in maximum height – and confounded by both a pattern of shoot die-back and the datum problems described previously. Significant shoot die-back was recorded in 11% of measured *D. masonii* individuals. This occurred when the uppermost branchlet or shoot died such that subsequent measurement, from the ground to the highest growing point were lower than previous measurements, and resulted in reduced, or negative height growth. No specific factor appeared to be responsible for this process, other than the normal process of branchlet longevity interacting with overall poor plant vigour. The health score of plants that died back averaged 1.5, while the average score for the other plants in the plots where die-back was observed was 2.6.

Across all sites and sample years, growth averaged 0.6 cm.yr$^{-1}$ among all plants (Table 11), but there was considerable annual and site-based variation, as well as between plants that died back or and those that did not. At 3.4 cm.yr$^{-1}$, mean seedling growth across both years was 6 times higher than the average for all plants. Seedlings which died-back grew at less than half this rate. In 2007-2008, when Iron Hill seedlings were five years old, their growth averaged 4.1 cm.yr-1, but this declined to 2.7 cm.yr$^{-1}$ in the following year. Height growth of plants in older sites followed a similar pattern, being lower in 2008-09 than 2007-08, and lower in plants with stem die-back. Overall, height growth of older plants was slightly negative (-0.8 and -1.0 cm.yr$^{-1}$). Only 2007-08 growth in the oldest (burnt <1969) sites had a positive mean value (2 cm.yr$^{-1}$).

**Table 11** Plant height growth rate (cm.yr-1; with ± SD and n) for tagged *Darwinia masonii* plants with varying time periods, time since fire and whether canopy die-back was recorded or not.

| Year last burnt | 2003 | 1969 | <1968 | Total older |
|---|---|---|---|---|
| 2007-2008 | 4.1 ± 5.5 (121) | -0.1 ± 15.0 (129) | 2.0 ± 6.6 (85) | 0.6 ± 12.1 (228) |
| 2008-2009 | 2.7 ± 9.5 (121) | -3.1 ± 13.8 (128) | -3.6 ± 7.7 (85) | -3.3 ± 11.7 (213) |
| mean 2007-2009 | 3.4 ± 5.0 (121) | -1.0 ± 4.1 (130) | -0.8 ± 2.8 (85) | -0.9 ± 3.7 (235) |
| Died back 07-09 | 1.5 ± 3.9 (21) | -2.5 ± 5.2 (12) | -4.1 ± 4.2 (4) | -2.9 ± 4.9 (16) |
| No d.b 07-09 | 3.8 ± 5.1 (100) | -0.8 ± 4.0 (118) | -0.7 ± 2.6 (81) | -0.8 ± 3.5 (219) |

The difference between positive height growth in seedlings and neutral or negative height growth in mature plants reflects the details of their growth form. Seedling growth focuses on the extension of a single erect shoot, whose

growth direction, and growing tip persists from year to year. This results in strong and sustained vertical growth – until plants reach maturity and flower, or the growing tip becomes damaged or dies. As flowering is terminal (occurs at the end of growing shoots) in *D. masonii,* reproduction means that shoot axes terminate and new growth develops laterally following reproduction. In older plants, new growth occurs via many dispersed branchlets growing in many different directions. This growth form does not encourage vertical growth, in fact, as branchlets die when they flower, and re-shoot laterally the canopy surface has a dynamism which may result in a fluctuating canopy height, with perhaps more net height growth in years of better growth conditions.

The pattern of variation in height with canopy width in *D. masonii* (Figure 7) shows increasing variation in canopy size with plant height once plants exceed 50-70cm in height, indicating the slower or more irregular nature of vertical growth in mature plants, as well as the propensity for older individuals to recline. That seedling growth was higher in 2007-08 than 2008-09 in seedlings and adults suggest better growth conditions in the earlier season.

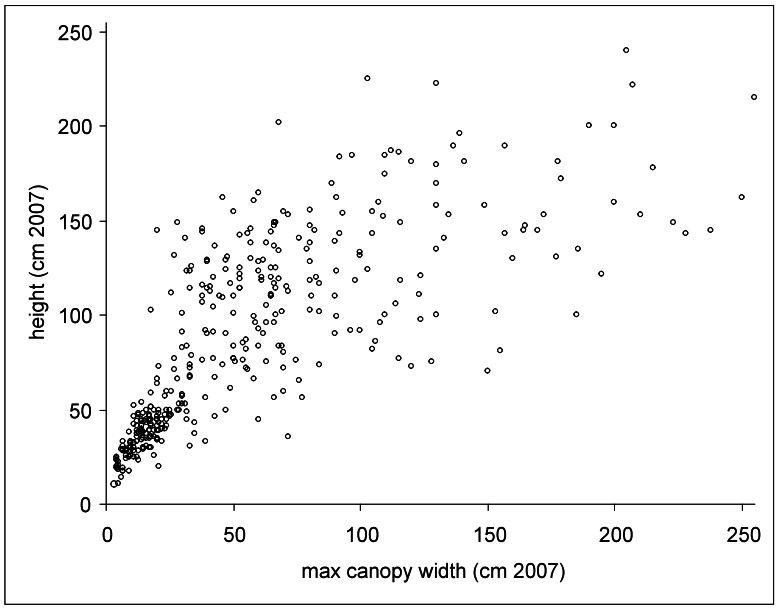



**Figure 7** Maximum canopy diameter varying with plant height in tagged *Darwinia masonii* individuals (2007).

The 12 May 2009 experimental fire enabled assessment of seedling growth at their initial stages. The first rains after the fire occurred May 21-22 (with 22 mm recorded at the Mt Gibson Oroya camp), and seedling germination can most conveniently be dated from this time. Seedlings were measured after 4 months, 6 months and 17 months. In late September 2009, four months after the fire, seedlings averaged 2.8 cm in height, by November they averaged 3.3

cm. Assuming negligible growth over the summer period, this provides an average growth rate of 7.2 cm.yr$^{-1}$. By October 2010, surviving seedlings averaged 5.9 cm, suggesting a much lower 2$^{nd}$ year growth rate of 2.7 cm.yr$^{-1}$. As rainfall in the winter of 2010 was well below average, this low growth rate may reflect a water limitation of growth, as much as an inherently slow 2$^{nd}$ year growth.

The mean measured rate of growth of tagged plants is considerably less than the mean rate of growth derived from their population structure and known fire ages (Table 8). The population structure data suggest a mean height growth rate of 9 cm.yr$^{-1}$ for seedlings up to 4 years old, and 2.9 cm.yr$^{-1}$ for plants up to 38 years. Our results indicate annual variation in growth rates, suggesting that the sample size (in terms of numbers of years) is not sufficient to accurately assess mean annual growth rates for this species. The estimate of growth rate to 38 years includes a period of growth as a mature plant, but also a juvenile period of higher growth. As a result, 2.9 cm.yr$^{-1}$ must be an overestimate of annual growth of mature plants. The length of the juvenile period is as yet unknown (but see *Fecundity* below).

Stem diameters were recorded for all plants in 2007 surveys, providing useful data on population structures, and then again for all plants in the 2003 fire areas and selected other individuals elsewhere in subsequent surveys. At the second survey, it became clear that slow growth rates, together with complications associated with remeasuring stems for older plants – due to bark swelling and sloughing, low branches and irregular cross-section shape – meant that the accuracy of stem diameter measurements was not sufficient for assessing individual growth rates on an annual basis. While 94 (of 247) of older plants were remeasured in 2008, remeasurement accuracy was such that 25% of these were not deemed adequate for comparison. Considerable variation in measured diameter growth rate was observed in the remaining 69 individuals (Table 12), and it is unclear to what extent measurement errors are responsible. The reported rate of 1.4 ± 2.6 mm.yr$^{-1}$ should be treated with some caution.

**Table 12** Plant stem diameter growth rate (mm.yr-1; with ± SD and n) for tagged *Darwinia masonii* plants with varying time periods and time since fire.

| Year last burnt | 1969 | 2003 |
|---|---|---|
| 2007-2008 | 1.38 ± 2.57 (69) | 0.14 ± 0.55 (87) |
| 2008-2009 | | 0.55 ± 0.58 (86) |
| 2007-2009 | | 0.34 ± 0.43 (112) |

Seedling stems have few of the problems listed for mature plants, and the measured mean rates and variation measured are more likely to reflect true growth patterns. Stem basal diameter growth of 4-6 year old seedlings averaged 0.34 mm.yr$^{-1}$ over the study, and was four times higher in 2008-09 than in the previous year (Table 12). Mean measured stem growth in these seedlings in their 6 and 7$^{th}$ years is about two thirds less than their mean growth in the preceding 5 years – as suggested by their mean diameters in 2007 (Table 8). The stem diameter of seedlings 17 months after the experimental fire averaged 0.84 mm, indicating a growth rate of 0.58 mm.yr$^{-1}$.

*Fecundity*

No tagged seedlings growing from the 2003 fire flowered in 2007 or 2008, but 6 of 115 (5%) surviving plants flowered in 2009. With heights of 51 to 95 cm these plants were all above average for seedlings of this age (45 cm), but made up just 13% of plants on this size range. It seems reasonable to suggest that 6 years is therefore the minimum age of reproduction for *D. masonii*, but to note that the proportion of plants flowering increases with plant size. The proportion of flowering plants also varies considerably between years, with 62% of all plants in older sites flowering in 2007, 36% in 2008 and 90% in 2009. In 2009, 93% of plants over 1m tall flowered.

The mean number of inflorescences per flowering plant also varied between years: averaging 29 in 2007, 5.6 in 2008 and 33 in 2009 (the 6 flowering seedlings averaged 2.3 inflorescences; Figure 19). This pattern reflects less flowering among smaller than larger plants and variation in the number of inflorescences produced by plants of different sizes (Figure 20).

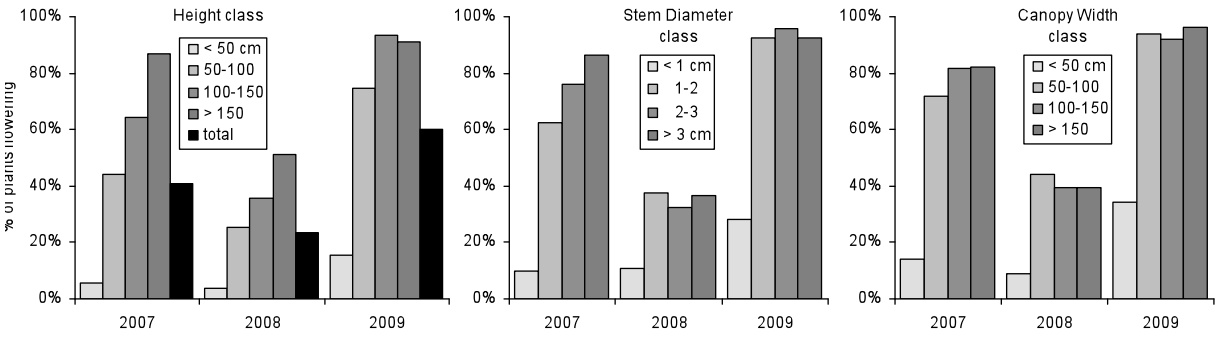



**Figure 19** Proportion of *Darwinia masonii* plants flowering / fruiting varying by size class and year: Stem height (cm), Stem diameter (mm) and Canopy width (cm) as measured in 2007.

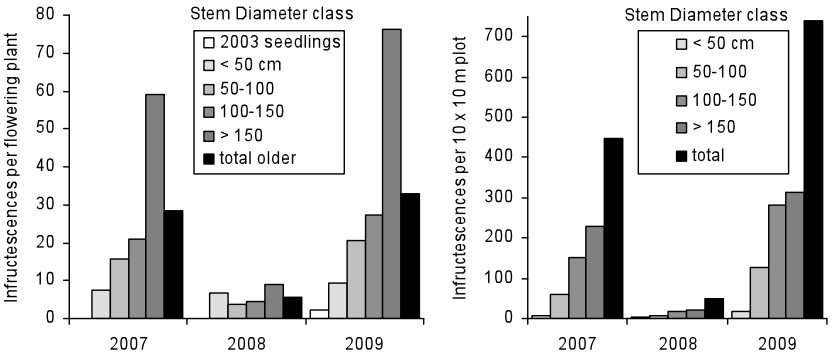



**Figure 20.** Inflorescence production per flowering plant (left) and per 10×10 m plot (right) varying by year and size class (canopy diameter) in older sites, as well as for seedlings from the 2003 fire.

The outcome of fewer flowering plants and fewer inflorescences per flowering plants is of course many fewer inflorescences per plot. In 2008, plants in the 10 older sites produced an average of 50 inflorescences per plot, but in 2007 and 2009 inflorescence production was 9 to 15 times higher (446 and 739 inflorescences per plot respectively; Table 13 )

**Table 13** Mean number of *Darwinia masonii* inflorescences per flowering plant and per 10×10 m plot varying between years and height class.

| | Height | per flowering plant | | | per plot | | |
|---|---|---|---|---|---|---|---|
| site age | class(cm) | 2007 | 2008 | 2009 | 2007 | 2008 | 2009 |
| | < 50 | 7.6 | 6.8 | 9.4 | 6.1 | 3.4 | 17.0 |
| 1969 + | 50 - 100 | 15.6 | 3.9 | 20.7 | 59.2 | 8.6 | 128.5 |
| Older | 100 - 150 | 21.1 | 4.5 | 27.3 | 149.8 | 17.6 | 280.8 |
| | > 150 | 59.1 | 8.9 | 76.2 | 230.4 | 20.4 | 312.5 |
| | Total | 28.6 | 5.6 | 33.0 | 445.5 | 50.0 | 738.8 |
| 2003 | all | - | - | 2.3 | 0 | 0 | 2.8 |

**Summary – *Darwinia masonii*:**

- The population structure of *D. masonii* indicates that most individuals recruit in a single cohort post-fire, with minimal inter-fire recruitment until populations age to (perhaps substantially) > 40 years. The oldest populations were more evenly structured, suggestive of infrequent inter-fire recruitment.

- Evidence from population structure suggests a mean stem diameter growth rate of 0.4 mm per year and a height growth rate of 2.9 cm.yr-1. Extrapolating these rates suggests that the oldest populations studied ('<1968') may have last burnt early in the 20th century, this estimation is crude, but suggests a fire around 1922.

- The survey of tagged plants confirms that interfire seedling recruitment is rare: just one new recruit was observed in the 15 survey plots over the 3 year period of the study, and that in an older site.

- Post-fire seedling recruitment is high, with as many as 3.2 seedlings produced per pre-fire adult. But mortality of these seedlings over the 1$^{st}$ summer following experimental fire was high, with 89-91% dying.

- Mortality among 4-6 year old seedlings was high, with 2.5-15% of seedlings dying each year.

- Death among 4-6 year old seedlings was highest among plants with low health scores, while the older plants that died were previously scored as healthy. Health scores varied considerably among seedlings, but little among older plants.

- Averaging 0.5% per year, mortality appears rare among plants in older sites in the absence of fire or extreme drought. The few deaths observed among plants in older sites were small plants, indicating an even lower mortality rate among older plants.

- Drought over 2010 appears to have contributed to a significant level of mortality of adult plants 10% in the Mt Gibson south population.

- Measured growth rates varied between years and younger and older sites. Negative height growth recorded for plants in older sites, may reflect poor growth conditions in measured years, but also difficulties in assessing plant size.

- Mean height growth averaged 7.2 and 2.1 cm.yr$^{-1}$ for 1 and 2 year old seedlings, 3.4 cm.yr$^{-1}$ for 4-6 year old seedlings. Mean height growth for older plants was close to zero or negative.

- Reproduction commences in seedlings as young as six years, but increases in terms of proportion of plants flowering, and flowers per plant as plant size increases.

- Total inflorescence production varied between years by more than an order of magnitude.

### *Lepidosperma gibsonii*

Eleven 5×5 m plots were established for demographic monitoring of *Lepidosperma gibsonii* (Figure 11, Table 14), within which live plants, including seedlings, were tagged with uniquely numbered aluminium tags. All clumps found were tagged and measured in most plots, in plots where seedling density was very high, all plants were counted, but a large subsample of seedlings were tagged and measured. Plots had between 13 and 311 plants each, and a total of 549 plants were measured and 862 enumerated. Five plots contained seedlings, and 36% of tagged plants were deemed to be seedlings at the start of the survey. All of the plots with seedlings had been burnt in the February 2003 Mt Gibson-Iron Hill fire.

**Table 14** Localities (midpoints) and fire ages of *Lepidosperma gibsonii* 5×5m demographic survey plots.

| Plot | Population | LAT | LONG | Fire history |
|---|---|---|---|---|
| LEHS1 | Extension Hill South | 29°34.950 | 117°09.925 | 1969 |
| LEHS2 | Extension Hill South | 29°34.967 | 117°09.863 | 1969 |
| LEHS3 | Extension Hill South | 29°35.083 | 117°10.000 | 1969 |
| LIH1 | Iron Hill | 29°36.272 | 117°10.380 | Older |
| LIH2 | Iron Hill | 29°36.287 | 117°10.505 | Older |
| LIHN1 | Iron Hill North | 29°36.007 | 117°10.226 | 2003 |
| LIHN2 | Iron Hill North | 29°35.991 | 117°10.240 | 2003 |
| LIHN3 | Iron Hill North | 29°35.934 | 117°10.337 | 2003 |
| LMTG1 | Mt Gibson | 29°35.652 | 117°11.056 | 1969, 2003 |
| LMTG2 | Mt Gibson | 29°35.662 | 117°11.052 | 1969, 2003 |
| LEF1 | Emu fence N | 29°33.640 | 117°10.883 | Older |

For each tagged *L. gibsonii* individual, we measured 'clump diameter' using digital callipers as the distance across the collected live leaf and culm bases – at 0-1cm from ground level. For each clump this was measured for both the longest and perpendicular dimensions. Inflorescence counts were made for all plants, and health was assessed using a 3-point subjective 'health' scale (Table 15). This was largely determined on the basis of relative foliage colour (noting that colour changes through the year – see below), growth and reproductive activity.

**Table 15** Qualitative health score for *Lepidosperma gibsonii.*

| Score | Plant vigour | New growth | Reproduction | Leaf colour |
|---|---|---|---|---|
| 0) | Dead or nearly | Absent | Little or none | Yellow-grey |
| 1) | Poor | Little | Few inflorescences | Green-yellow |

| | | | | |
|---|---|---|---|---|
| 2) | Good | Vigorous | Many inflorescences | Green |

*Population structure*

Population structure – the distribution of individuals across size classes – provides information on population processes and recruitment dynamics. The surveyed populations of *Lepidosperma gibsonii* varied considerably in their structure, with a number of distinct patterns distinguishable (Figure 21). Three of the five sites in areas burnt in 2003 showed a clear pulse of seedling recruitment following that wire, with the majority of individuals being seedlings. Seedlings were also found in the two remaining burnt plots, but not in abundance. No plant in any recently burnt area exceeded 20cm in diameter (Table 16). Two plots on Extension Hill South had a strong peak in plant sizes around 10cm and 14 cms respectively and both were probably last burnt in the 1969 fire, again few plants in these sites exceeded 20cm in diameter.

The remaining sites were last burnt at some time prior to 1968 and had fewer individuals but these did include all of the largest plants in the study. Two of these sites have a flat size distribution – indicating either a long period in which plants grew at varying rates or during which occasional recruitment contributed individuals at different times which now represent of a variety of ages. The smallest plants in these sites were 4-5cm and the largest 40-48 cm across at the base. The last site – Iron Hill N1 – had the lowest density of individuals and is therefore harder to interpret, however all individuals at this site were >9 cm and the largest was 32 cm.

**Table 16** *Lepidosperma gibsonii* mean plant size in relation to fire history

| plot | code | fire history | mean base diam (cm) | no of plants | Seedlings | Mature <20cm | Mature >20cm |
|---|---|---|---|---|---|---|---|
| Emu Fence | EF | <?1969 | 26 | 14 | none | few | few |
| Iron Hill 1 | IH1 | <?1969 | 15 | 15 | none | few | few |
| Iron Hill 2 | IH2 | <?1969 | 18 | 23 | none | few | few |
| Extension Hill South 1 | EHS1 | 1969 | 7 | 66 | none | many | few |
| Extension Hill South 2 | EHS2 | 1969 | 10 | 19 | none | some | none |
| Extension Hill South 3 | EHS3 | 1969 | 8 | 77 | none | many | few |
| Iron Hill North 1 | IHN1 | 2003 | 11 | 13 | few | few | none |
| Iron Hill North 2 | IHN2 | 2003 | 6 | 15 | few | few | none |
| Iron Hill North 3 | IHN3 | 2003 | 2 | 67 | many | few | none |
| Mt Gibson 1 | MG1 | 1969, 2003 | 2 | 45 | many | some | none |
| Mt Gibson 2 | MG2 | 1969, 2003 | 2 | 127 | many | some | none |

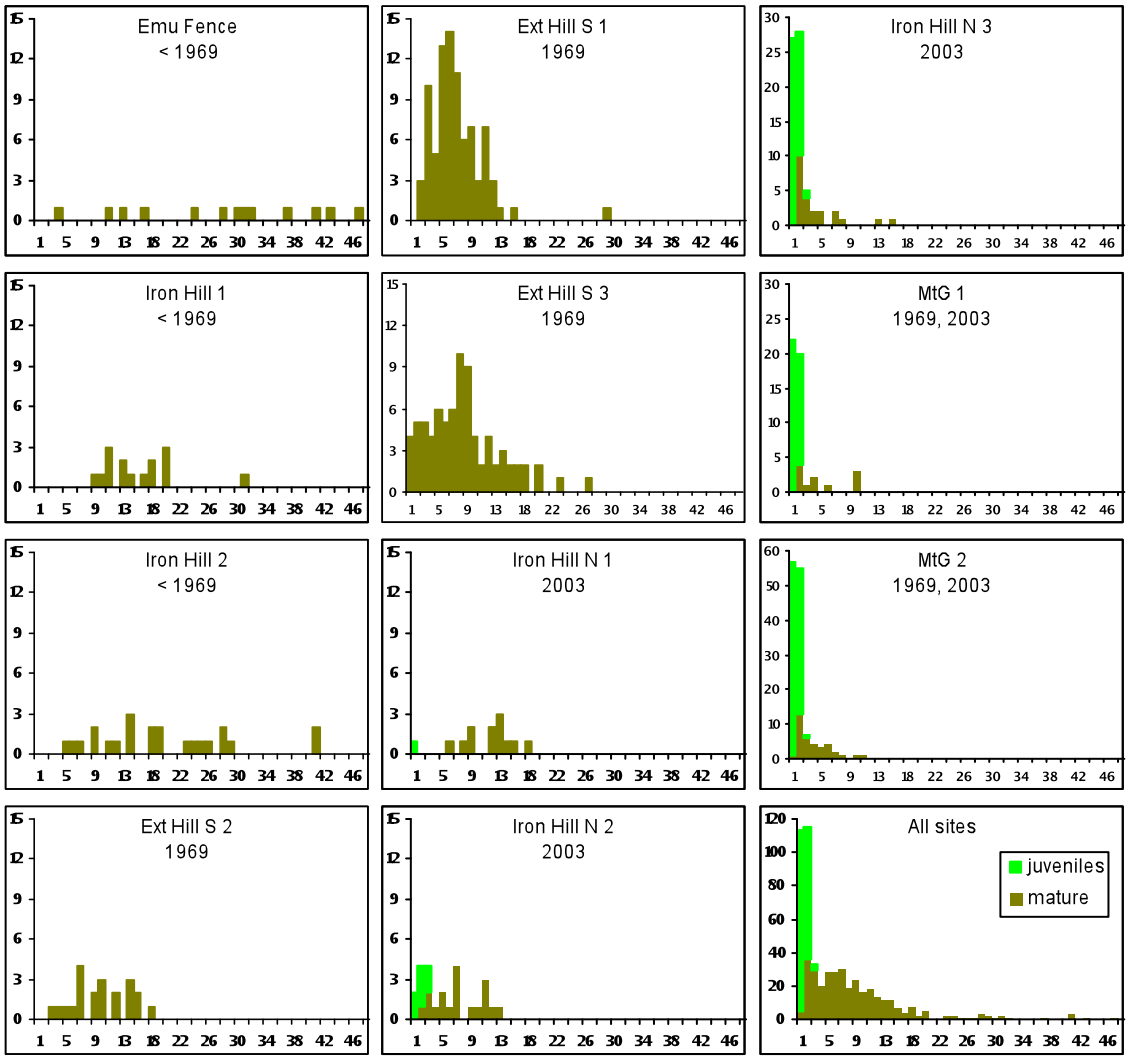



**Figure 21.** Population structure of surveyed Lepidosperma gibsonii plots. Number of Lepidosperma gibsonii plants (Y-axis) classified by size (X-axis: maximal clump diameter at ground level, 1cm increments). Data from 2007 survey of eleven 5×5m plots. Plots with seedlings were all burnt in a 2003 wildfire, other sites unburnt since prior to 1970 – year given.

These results indicate an important role for fire in determining the population structure and population dynamics of *L. gibsonii*. Firstly, the presence of both adults and seedlings in the most recently burnt sites indicates that at least some mature plants can survive wildfires but also that fires stimulate a large number of soil-stored seeds to germinate. The absence of seedlings in other sites suggests that fire is actually required for seedling recruitment, however the flat population structures of the oldest sites suggest that inter-fire recruitment might also occur. The high population densities, peaked population structures and smaller mean plant sizes in areas burnt only in 1969 suggest strong post-fire recruitment with few individuals surviving from the previous fire period. If that is so, with a mean plant size of 7-10cm and

population age of 38 years would suggest a mean growth rate of ~ 2 mm per year. Seedlings deriving from the 2003 fire averaged 1.02 cm diameters and therefore a comparable 2.5 mm base diameter expansion per year. If these mean growth rates are consistent between sites, then the emu fence population could be 100 years old.

*Recruitment*

No *Lepidosperma gibsonii* seedlings were observed in study plots outside of areas burnt in 2003 or 2009. It is assumed that effectively all seedling recruitment occurs following fire. Seedling recruitment in areas burnt in 2003 was spatially very variable, with counts in 5 × 5 m plots burnt in 2003 of 1 to 261 seedlings (Table 17). This variation was equivalent to around 0.1 – 5.2 seedlings per pre-fire adult and post fire seedling densities from 0.04 to 10.4 per $m^2$. The extremes all occurred among Iron Hill North sites: two, both facing SW and respectively at the top and bottom of one shallow gully had very low recruitment rates, while the third site with high recruitment had a similar aspect but was in a protected site on the side of a deeper canyon. If mortality among pre-fire individuals (determined from counts of burnt clumps still visible as blackened leaf bases in 2007) is an indicator of fire intensity, the two sites with the lowest post-fire recruitment had both the highest and the lowest fire intensities.

**Table 17** *Lepidosperma gibsonii* fire survival and recruitment data (2003 wildfire).

| Plot | IHN1 | IHN2 | IHN3 | MG1 | MG2 | all |
|---|---|---|---|---|---|---|
| pre-fire density (/m2) | 0.5 | 2.8 | 2.0 | 0.4 | 2.0 | 1.5 |
| % killed in fire | 0 | 74 | 18 | 0 | 24 | 38 |
| seedlings per pre-fire adult | 0.1 | 0.1 | 5.2 | 3.5 | 2.0 | 2.1 |
| seedling density (/m2) | 0.04 | 0.3 | 10.4 | 1.5 | 4.0 | 3.2 |
| Pop. growth (2003 - 2007) | 1.1 | 0.4 | 6.0 | 4.5 | 2.7 | 2.7 |

In the spring following the May 2009 experimental fire, 229 seedlings were counted in three marked plots (Table 18). No new *L. gibsonii* seedlings were found in the fourth plot, which contained just one adult (and many *Darwinia masonii*). The density of seedlings ranged from 0.5 to 7.9 per $m^2$ and averaged 2/ $m^2$ (discounting plot four). The number of new seedlings per adult averaged 4.2 and varied from 1.3 to 12.8 among the three plots.

**Table 18** *Lepidosperma gibsonii* fire survival and recruitment data (experimental fire in May 2009, seedlings assessed October 2009).

| Plot | # | 1 | 2 | 3 | 4 | All* |
|---|---|---|---|---|---|---|
| | area $m^2$ | 100 $m^2$ | 25 $m^2$ | 25 $m^2$ | 100 $m^2$ | 250 $m^2$ |
| Adults | no. | 4 | 28 | 44 | 1 | 77 |
| | % killed | 50% | 48% | 56% | 0% | 54% |
| Seedlings | no. | 51 | 197 | 53 | 0 | 229 |
| | density /$m^2$ | 0.5 | 7.9 | 2.1 | 0 | 1.2 |
| | per / adult | 12.8 | 7.9 | 1.3 | 0 | 4.2 |

*Survival / Mortality*

Survival of *L. gibsonii* individuals was spatially and temporally variable, and differed between adults and seedlings. While plants are killed in fire, a proportion also survives fire. Mortality of pre-fire adults ranged from 0 to 74 % (Table 17) in the 2003 wildfire, while 54% of the 77 pre-fire adults burnt in the 2009 experimental fire were killed (Table 18). The mortality estimate from the 2003 fire is derived from counts of both resprouting individuals and observed burnt and non-resprouting plants. Burnt and non-resprouting plants are visible for some years post-fire as blackened leaf bases, but it is possible that a number of these were missed in the survey as they can be harder to find, and others may have degraded post-fire or were burnt to an extent that no evidence exists. Hence, the proportion given here of plants killed in the 2003 fire is likely an underestimate. Nonetheless, it is clear that this value is quite variable.

Mortality of older seedlings (i.e. of plants surveyed 2007-2010, emerging following the 2003 wildfire) averaged 3% per year (Table 19), but varied between years within sites. Among adult plants, mortality varied from 1 to 5% per year across all sites and also averaged 3% per year. However, most mortality occurred in a single plot. Of the 26 older plants observed to die over the course of the study 19 were in the EHS1 plot where 20% of plants died in one year (Table 19). This plot was first surveyed with 66 live plants: a comment noting 17 dead plants recorded at that time suggests a history of population decline at this site. Examination of dead plants revealed no clear cause of death. This site is not notable for any unusual environmental features. It quite high on the slope, and has relatively little catchment area above, although as *L. gibsonii* individuals do occur higher up the slope, it is not at the upper limit for the population.

Survival of seedlings that emerged following the experimental fire was markedly lower. Of the 230 seedlings marked in the first winter following the fire, the plant or tag of all but 12% was refound after the following winter. Of the 2020 refound plants 72% had died. If the not-found plants are assumed to have died, the mortality rate would be 76%. Wire mesh cage was placed over 37 seedlings to exclude vertebrate herbivores: 73% of these plants died.

**Table 19** *Lepidosperma gibsonii* mortality data for plots burnt in 2003 (IHN, MG) and in older plots (EHS, EMN IH).

| Plot | IHN1 | IHN2 | IHN3 | MG1 | MG2 |
|---|---|---|---|---|---|
| count | 1 | 7 | 257 | 38 | 99 |
| % dying: seedlings 2007/08 | 0 | 14.3 | 0.8 | 7.9 | 7.1 |
| % dying: seedlings 2008/09 | 0 | 0 | 4.7 | 0 | 0 |
| count | 12 | 18 | 41 | 11 | 38 |
| % dying: adults 2007/08 | 0 | 0 | 0 | 0 | 7.9 |
| % dying: adults 2008/09 | 0 | 0 | 0 | 0 | 0 |

| Plot | EHS1 | EHS2 | EHS3 | EMN1 | IH1 | IH2 |
|---|---|---|---|---|---|---|
| count | 103 | 21 | 87 | 16 | 15 | 23 |
| % dying: adults 2007/08 | 1.2 | 0 | 0 | 0 | 0 | 0 |
| % dying: adults 2008/09 | 20.2 | 0 | 2.3 | 0 | 0 | 0 |

*Health scores*

It proved difficult to determine a subjective, quantitative health score for *L. gibsonii* to more than three classes - based on apparent plant vigour, colour, and inflorescences production. With one of these classes representing dead or dying plants, the majority of scored individuals fell into the healthiest class, with very few or none scored as 0. The proportion of healthy plants varied from 66% of surveyed adults in 2008 to 99% of seedlings in 2009 (Table 20).

**Table 20** Proportion of surveyed seedling and adult *Lepidosperma gibsonii* individuals with a health score of 2 (i.e. maximal).

| | 2007 | 2008 | 2009 |
|---|---|---|---|
| Adults | 89% | 66% | 95% |
| Seedlings | 89% | 85% | 99% |

*Growth*

The indeterminate and modular growth form of *L. gibsonii* clumps means that clumps can expand and contract in size, and this was observed (Figure 22). Older clumps often consist of live and dead sections, with measurements made across the longest dimension of the base between live parts. If one distant live section died then a clump could show a sudden large decrease in

size. Over the period July 2007 – July 2009 the basal diameter growth rate of seedlings averaged 0.35 mm / year, while that of adults averaged -2.4 mm / year (Table 21). Seedlings averaged 6.3 mm growth in the first surveyed year and -5.0 mm in the next. Adult growth averaged -1.2 mm in -4.7 mm across consecutive years.

**Table 21.** Growth rate of *Lepidosperma gibsonii* clumps (of basal diameter, in longest dimension and perpendicular) in mm per year.

| | 2007-2008 | 2008-2009 | 2007-2009 |
|---|---|---|---|
| **Longest dimension** | | | |
| adult | -1.2 | -4.7 | -2.4 |
| seedling | 6.3 | -5.0 | 0.3 |
| **Perpendicular to longest dimension** | | | |
| adult | 3.0 | -3.8 | -1.8 |
| seedling | 5.3 | -4.3 | 0.1 |

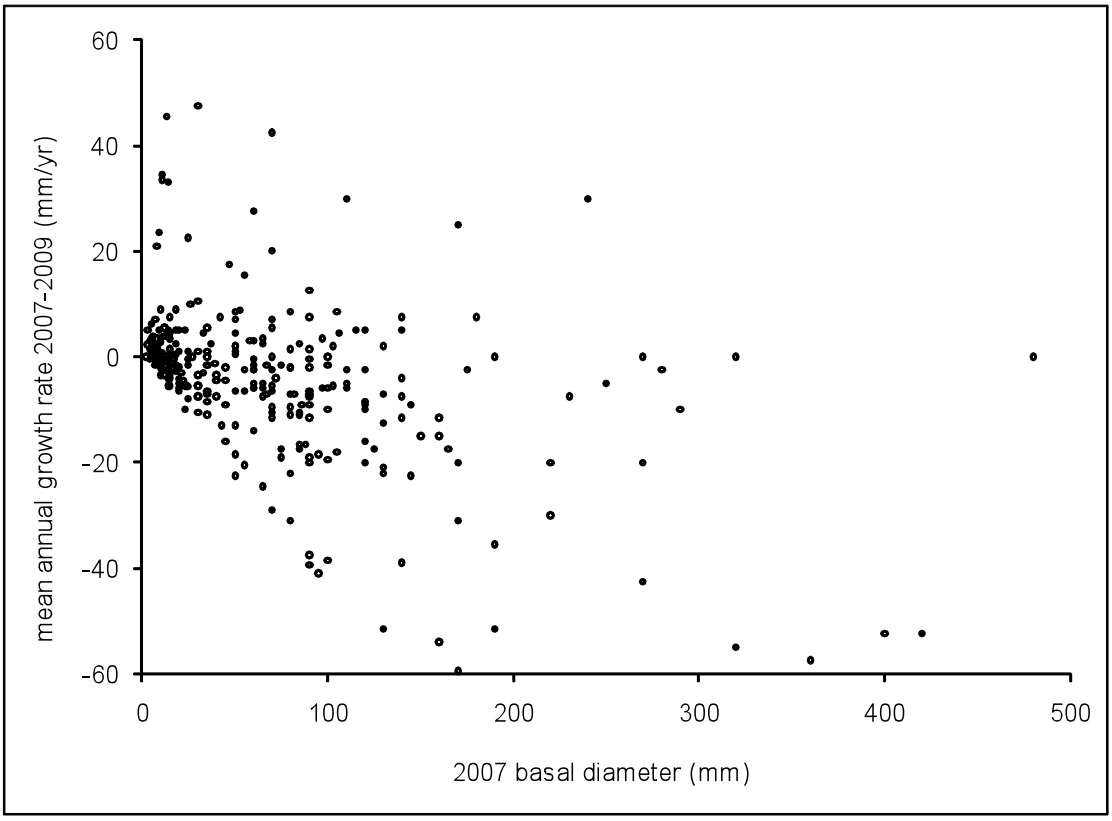



**Figure 22** *Lepidosperma gibsonii* mean annual growth in relation to initial plant size (both of base diameter)

*Fecundity*

In 2007 57% of plants with a base diameter (bd) over 8 cm had infructescences indicating fruit production in 2006 and 39% of plants over 8cm bd had inflorescences ready for flowering in 2007. Flower and fruit production

was observed among even the smallest individuals, with 7% of those < 1cm bd flowering and 4% fruiting. The proportion of reproductive plants increased through to 60 mm (for flowering) and 100 mm (for fruiting), and there was some evidence for reduced reproduction in the largest plants (Figure 23).

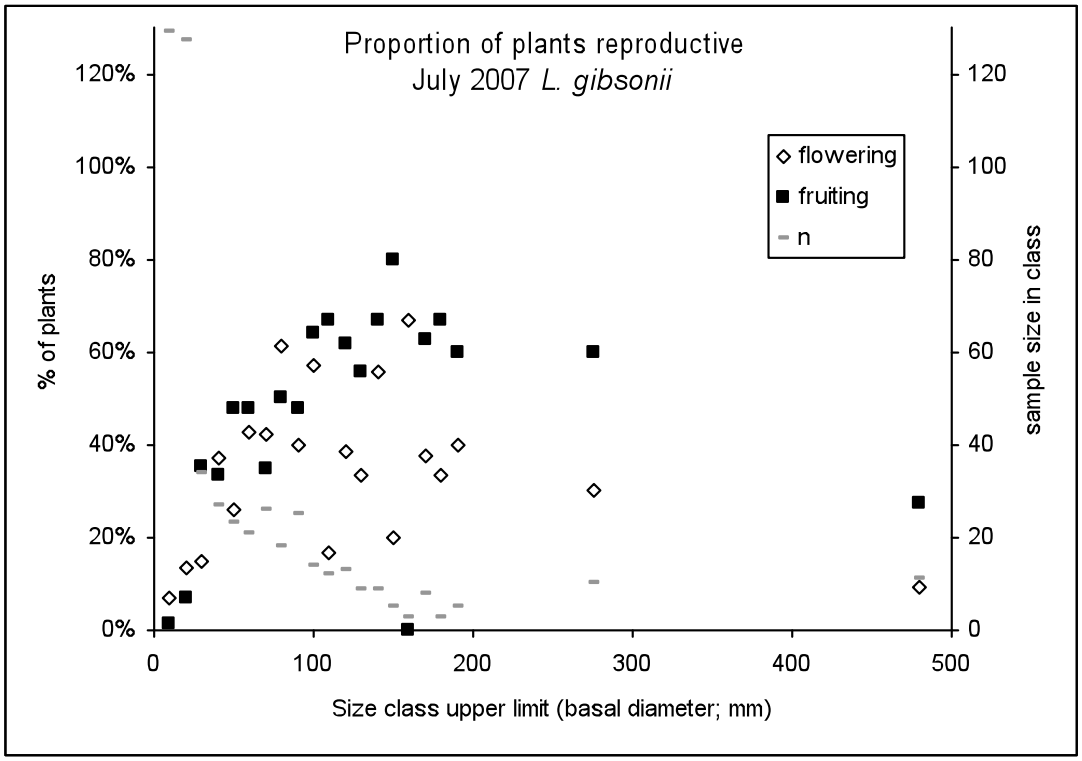



**Figure 23** Proportion of plants in 2007 with flowers developing (for fruit production later in the year), or with evidence of fruits from 2006 varying with clump size.

**Summary – *Lepidosperma gibsonii*:**

- Population structure of *L. gibsonii* indicates that individuals recruit in a single cohort post-fire, with no evidence for inter-fire recruitment observed. That older populations were evenly structured, may suggest infrequent inter-fire recruitment, but are more likely to indicate varying growth rate and the coalescence and splitting of clumps through time.

- Evidence from population structure suggests a mean basal diameter growth rate of 2 – 2.5 mm per year for seedlings and adults.

- Extrapolating growth rates from population structure suggests that the oldest populations studied ("Emu Fence") may have last burnt early in the 20th century, perhaps around 1910.

- Post-fire recruitment was higher, with an average of 4.2 seedlings produced per pre-fire adult.

- Considerable spatial variability in post-fire seedling recruitment was observed following both wildfire and experimental fires, with burnt sites recording 0.1 – 12.1 seedlings per pre-fire adult.
- Approximately 50% of plants are killed in fire, the remainder produce new leaves from buds surviving among burnt leaf bases
- Mortality is variable among plants in older sites, averaging 3% per year overall, but largely due to 20% mortality observed in one year in one plot.
- Mortality among 4-6 year old seedlings was similar, with an average of 3% of seedlings dying each year.
- Mortality among seedlings over the first summer and winters following fire (and germination) was much higher; 72-76%.
- Measured growth rates varied between years and smaller and larger plants. Negative growth recorded for many plants, reflects poor conditions in measured years, but also difficulties in assessing plant size.
- Mean measured seedling basal diameter growth averaged 0.3 mm / year, while mean growth for older plants was -2.4 mm / year.
- Reproduction commences in seedlings as young as six years, but increases in terms of proportion of plants flowering, and flowers per plant as plant size increases.
- Total inflorescence production varied between years by more than an order of magnitude.

## 4.3 BREEDING BIOLOGY

### 4.3a Phenology

We divided the reproductive cycle of each species into discreet stages based on non-invasive observable measures, and monitored numbers of inflorescences per plant at each stage over an entire reproductive season in 2009. For each species, five plants in each of four populations were visited at 2-3 week intervals, and the number of flowers at each developmental stage was recorded.

***Darwinia masonii***

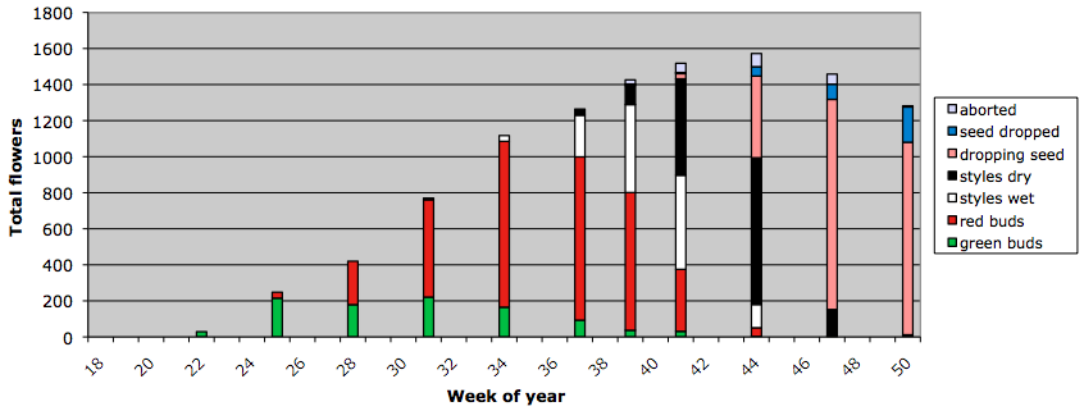



**Figure 24** Phenology of developmental stages in *D. masonii*. Total of 20 plants assessed, 2009.

**Table 22** Categories employed for assessing the phenology of *D. masonii* populations.

| | |
|---|---|
| Green buds | New buds initiated (counted when clearly differentiated from leaves) |
| Red buds | Buds swollen but flowers not yet open (bud development stage) |
| Styles wet | Flowers at anthesis – actively donating and receiving pollen |
| Styles dry | Flowers with shrivelled styles but seed unripe (seeds maturing) |
| Seed ripe | Infructescences (flower heads) dropping seed |
| Seed dropped | All seeds dropped |
| Aborted | Development ceased at some stage prior to complete ripening |

Floral initiation commences at the start of winter, with flowers opening from late August through to late October. Ripe seeds are first apparent in mid to late October and continue to ripen through to late November. Peak flowering (anthesis) in 2009 occurred about week 40 (first week of October). The 2009 season started late (no rain until late May), and was clearly extended by good

late rains in October. In a more “normal” season plants have open flowers about 2 weeks earlier.

Optimal seed collection time is about when about number of infructescences yet to drop seeds = number with dropping seed. In 2009, this occurred around mid November. Note the broad initiation time (May-September) means that there are some flowers at all stages of development until the very end of the season, so the presence of *some* undeveloped seed is not a good indication of maximum seed availability. Seeds also drop rapidly, often with the bracts following quickly behind, so that it is then difficult to estimate the amount of seed already gone. Ants quickly remove seeds from around plants, so seed cannot be easily collected from the ground (see **4.3f Dispersal**). The most effective method of seed collection is from the plant, by hand during November – in most seasons at least some seed can be collected throughout the month (by agitating seeds within the drier flower-heads when still on the plant, and collecting seed that easily falls out). Note also that seed quality will probably depend on competing factors: earlier-developed seed is more likely to have been effectively pollinated (rather than inbred) because lower temperatures keep nectar liquid and attract more pollinators; styles are also less likely to be heat-damaged). However, predation by seed-eating moth larva (**4.3b Seed production**) may also be more prevalent earlier in the season, although this affect has not been quantified, and seems to vary considerably between population and season.

Seed drop is also progressive, with an average of around 10% of seed fallen from seed heads in late October, 50% by mid November and 90% fallen by December. A few (probably unfertilised) flowers remain attached to the inflorescence to late in the season, so the average percentage of seed dropped is a more accurate measure of seed maturity than number of heads with all seed dropped. Moth larvae in some infructescences prevent developed seeds from falling by attaching them to the infructescence-base (technically, the disk or receptacle) with silk threads. As fruits fall from un-infested infructescences through summer, the proportion of remaining infructescences that are predated by moth larvae increases: so some infructescences may appear to still be holding ripe fruits later in the season, but these may be predated and empty (Figure 25).

A small percentage of buds aborted, with a peak around late October as increasing daytime temperatures cause damage to buds and fresh flowers.

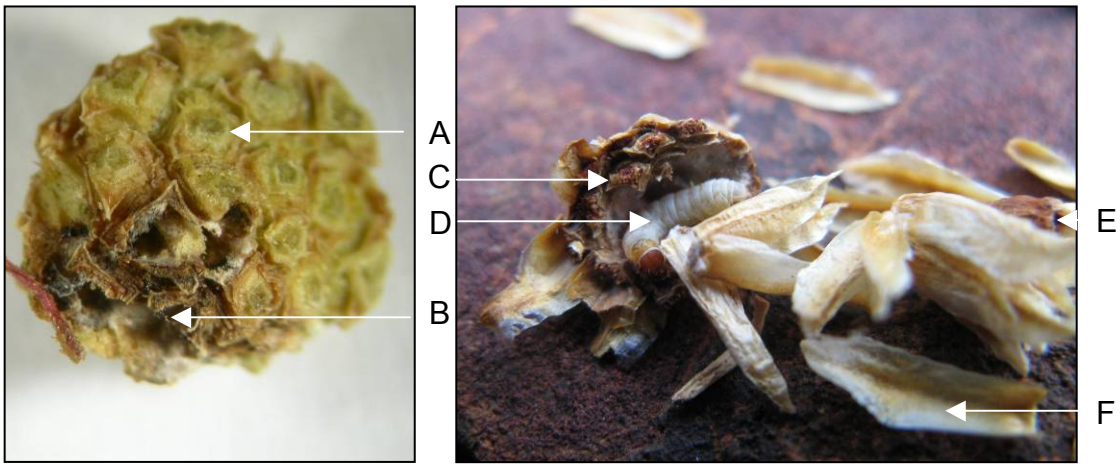



**Figure 25** Left: The disk (or receptacle) of a *Darwinia masonii* inflorescence with flowers/fruits and bracts removed showing ~23 insertion sites for flowers/fruits (**A**), including a number which have been hollowed out by a moth larva (**B**). Right (April 2008): a receptacle (**C**) opened showing moth larva (**D**) with dried bracts (**E**) and fruit (**F**) retained.

### *Lepidosperma gibsonii*

Flowering and fruit production in *Lepidosperma gibsonii* is a process which takes almost 18 months from initiation to seed release (

Table 23). Flower initiation commences with the initiation and extension of reproductive inflorescences or culms in late winter / early spring, culms cease development as they reach a length similar to or slightly longer than that of existing leaves, and then remain dormant over summer. Flower development is complete in April or May of the next year and the wind dispersed pollen is released in a synchronised burst correlated with stigma elongation, lasting only a couple of weeks (occasional flowers are still receptive for another couple of weeks; Figure 26).

Under ideal conditions, fruit development of pollinated flowers continues through winter and ripe seeds are released from infructescences during a brief period in late September-October (

Table 23). Undeveloped fruits and old infructescences usually remain on the plant over the following summer and into the next growing season. Thus successful seed development requires suitable conditions (i.e. sufficient soil moisture) for inflorescence development in spring of one year and suitable conditions again over the winter and spring of the next year. At any one time, evidence of two or three annual reproductive sequences may be visible on plants. Depending on the progress of their respective development and ageing, distinguishing between these is sometimes easy and sometimes

difficult. It is particularly difficult to distinguish current year's inflorescences from the previous season's inflorescences after about July. It is therefore necessary to remove all inflorescence apices over summer to be able to score the number of new inflorescences produced each year (leaving the green part of the culm to prevent loss of photosynthetic area).

**Table 23** Timing of reproductive events in *L. gibsonii.*

| Event | Time | Duration | Dependence |
|---|---|---|---|
| Anthesis (pollen release and pollination) | late April to mid June | 2-4 weeks | Presence and number of inflorescences depends on the previous season (may be very low). Timing of anthesis depends on heavy autumn dew and break of winter rains. Effective pollen release and stigma receptivity dependent on humid conditions. Anthesis is rapid and highly synchronised, with few flowers at anthesis outside of a 2-week period. |
| Gradual development of seed | Following anthesis to Nov | 4 months | Depends on onset of anthesis and spring rains (which prolong development) |
| Emergence of new inflorescences for the break of the following season | August -November | 1-4 months | Prolonged and increased numbers with spring rainfall |
| Seed release of viable seed (inviable seeds held on plant) | September-November | 1-2 months | Seeds released more rapidly in drier conditions |
| Optimal seed collection (only 1 year observed with sufficient seed production) | Late September - Early October | c. 2 weeks | Seeds released more rapidly in drier conditions. NOTE: Post seed-release, inviable seeds are held on the plant and give false impression of seed availability. |

By mid October in 2009, previously green seed (actually the fruit, a tiny thin-walled nut that contains one seed) had become brown and could be caused to fall by lightly running one's hands along the inflorescence. This was later confirmed, via X-ray analysis, to be the ideal time for seed collection – in terms of % of seeds filled. Examination of X-ray photographs of seeds in a Faxitron X-ray Corporation v1.2 (exposure 21kV for 10 seconds) camera reveals wether fruits contain filled seeds or not (Figure 27). *Lepidosperma gibsonii* fruits may be retained on infructescences for some time, but it the proportion of filled seed among retained fruits is much lower than among fruits which fall from the plant (Figure 28).

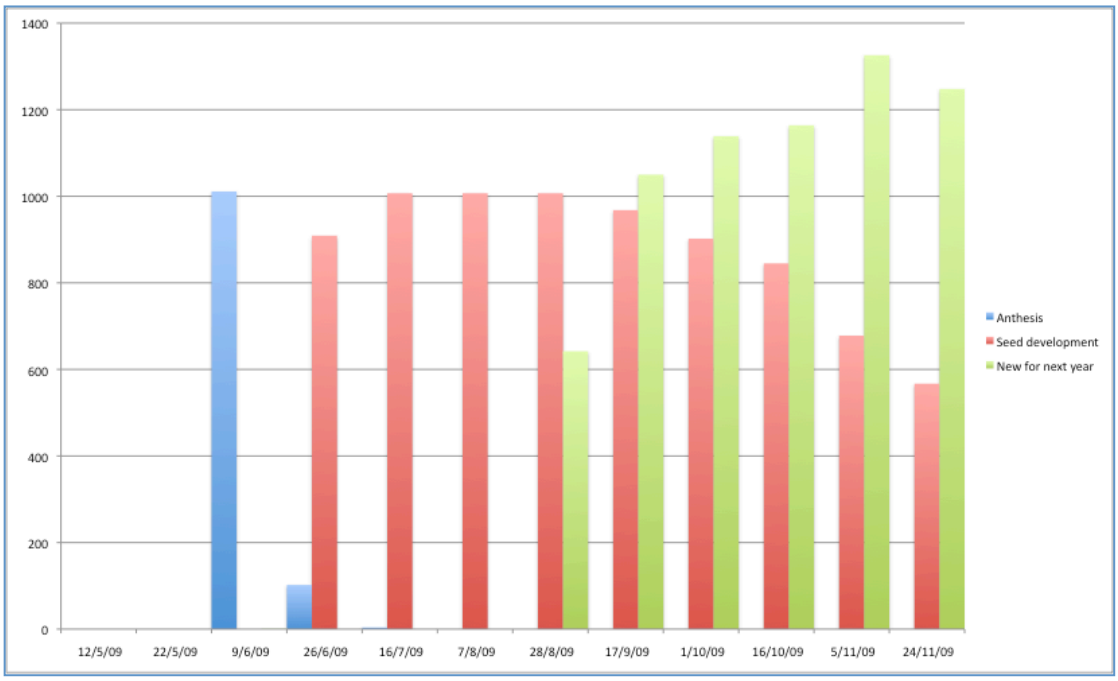



**Figure 26.** Relative number of inflorescences at differing development stages during 2009, showing rapid burst of anther release (and stigma receptivity), inflorescences developing seed, and production of new inflorescences for the following year. The y – axis is a total count of inflorescences at each stage, summed over 40 plants from 4 populations, as observed every 2-3 weeks over the growing season.

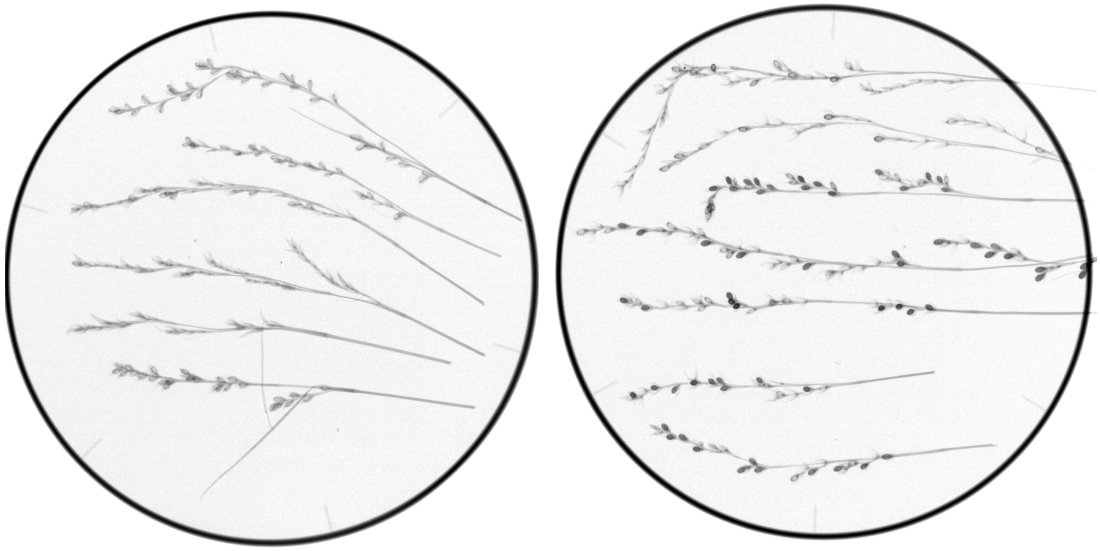


**Figure 27.** X-ray images of *L. gibsonii*, showing (left) developing seed from earlier in the season, unfilled and x-ray transparent; (right) developed seed from early October clearly showing developed seed (dark and x-ray opaque), and non-viable seed (pale, x-ray transparent. The darker seeds in the second image are ready to drop, while the non-viable seeds will remain on the plant, presumably to confound seed predators (and seed collectors).

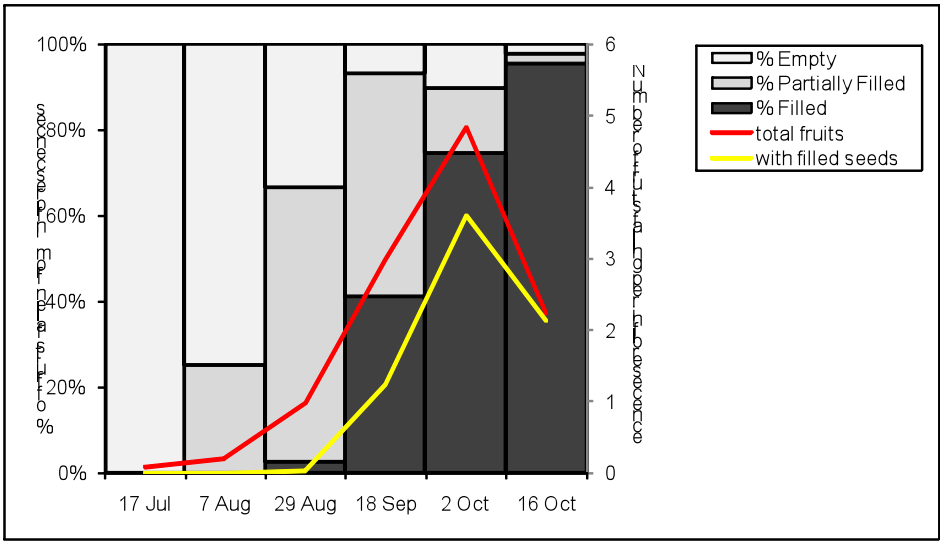



**Figure 28.** Proportion (bars) and number (lines) of filled fruits falling from *L. gibsonii* inflorescences (mean of ten inflorescence from each of four sites). Proportions are of fruits fallen at the sample time. Seed collection during late Sept-early Oct is possible, but the peak seed production (yellow line) is relatively short, as filled seed drop rapidly. In the field ripe seed can be detected by lightly running fingers along an inflorescence and counting the number of seed thus released.

## Summary

- *Darwinia masonii* flowering and seed production takes place over a long period in spring and early summer.
- The peak period for *D. masonii* seed collection depends on the relative rates of seed development and seed drop, and may vary between years and localities, but in 2009 occurred around mid November.
- *Lepidosperma gibsonii* reproduction takes place over multiple years, with inflorescence production occurring in one year and flowering and fruit ripening occurring in the next.
- The seed collection window for *L. gibsonii* is brief (one to two weeks) as filled seeds fall soon after ripening. In this study mid October was found to be the ideal time for seed collection.

## Recommendations

- Seed collection is timed closely to ensure that collected material contains viable filled seed.
- Ideal collection times appear to be mid November for *D. masonii* and mid October (in fruiting years) for *L. gibsonii*.

### 4.3b Seed production

***Darwinia masonii***

Seed production was assessed by counting the number of fruits in each of 30 infructescences collected from plants in the vicinity of each survey plot in each year. Seed fill rate was assessed by X-ray photography, and fruits with visible signs of external damage were counted as predated. Seed production per plant was calculated using these numbers together with the data on mean infructescences per plant and proportion of flowering plants reported previously (Table 13).

**Table 24** Number of *D. masonii* fruits produced, number of filled seeds and number of predated seeds per infructescence (infr), as well as total seed production per plant for 2007-2009.

| | 2007 | 2008 | 2009 |
|---|---|---|---|
| Flowers / infructescence | – | – | 22.1 |
| Fruits / infructescence | 17.3 | 14.7 | 10.4 |
| Filled seeds / infr (% of total) | 2.6 (15%) | 4.5 (30%) | 2.0 (19%) |
| Predated seeds / infr (%of total) | 1.1 (6%) | 1.8 (11%) | 2.3 (22%) |
| Uneaten seeds / flowering plant | 75 | 25 | 66 |
| Uneaten seeds per plant | 47 | 9 | 59 |

Each flower in a *D. masonii* inflorescence has the potential to develop into a single fruit, each of which may in turn hold a single seed. However, when assessed in 2009, the number of developed fruits per infructescence was just under half the mean number of flowers per inflorescence (Table 24). Slightly fewer fruits developed per infructescence in 2009 (10.4) than in previous years (14.7 in 2008 and 17.3 in 2007). Externally indistinguishable, empty fruits (i.e. not containing developed seed), outnumbered filled fruits (containing developed seeds) in each year surveyed. With 70 - 85% of developed fruits not containing filled seeds, and the rate of seed predation varying between 6 and 22% per year, the mean number of good seeds that escaped predation varied from 2 to 4.5 per infructescence. Multiplying seeds per infructescence by the number of infructescences produced per flowering plants and the proportion of flowering plants in each year indicates that on average, between 25 and 75 good seeds are produced per flowering plant. Including non-flowering plants, this means an average of 9 – 59 seeds per plant per year in older plots.

Predated seeds are almost entirely all eaten by larvae of an unknown moth species. The moth prevents fruits from dispersing from infructescences by sewing them together with silk, and these are then retained on the plant for months after the fruits of non-predated infructescences have dispersed. The

moth appears to survive summer in its larval stage, and has been observed in April living inside the hollowed out floral disk or inside a sewn-on fruit.

In 2008, filled fruits weighed an average of 6.4 ± 0.6 mg each (n = 976).

***Lepidosperma gibsonii***

The production of inflorescences and infructescences varies between plants in *L. gibsonii* as well as between plots and years. As described above (4.3a) *L. gibsonii* inflorescences develop over winter, become dormant over summer and flower and ripen seeds in the next winter. These inflorescences (which have green stems, i.e. photosynthesise) may also be held for a third year following seed production with the old reproductive parts still attached. Thus at any one survey time, plants may support evidence for reproduction across three years. At most seasons it can be difficult to distinguish old from developing infructescences.

As seed production requires two consecutive years of good rainfall for both culm initiation and development in one year, and flowering and fruit ripening in the next, and although it is not known what the threshold rainfall requirement is for these processes, it is possible to model seed production through time. With the exception of 3 years (1968, 1971 and 1972) the Ninghan annual rainfall record is continuous back to 1905. (Regionally, 1968 was above average, 1971 was average and 1972 below average). Seed production was observed in 2009, and rainfall at Ninghan in 2008 and 2009 was 130% and 110% of the average respectively. 2006 and 2007 had 63% and 107% of average rainfall, but seed production was not observed in 2007, suggesting that the minimum rain must be >63%. Thus the rainfall threshold is likely to be between 63% and 110% of the annual average.

Modelling of the sequence of years with rainfall receipt above a threshold percentage of the Ninghan long term average and reporting the years which are themselves both above the threshold and preceded by an equal or better year indicates that potential years of seed production are infrequent and clustered. If the limiting threshold for seed production is the same for both years of development and equal to (i.e. 100% of) the long term average rainfall, then seed production could occur in 22% of years, if this threshold is 110% of the mean rainfall, then fruit production would only have occurred in 10% of years. While these scenarios indicate an average of one year of seed production every 4.5 years and one per 10.5 years respectively, the actual run of years without seed production is very different. The 106-year Ninghan record indicates one period of 17 years without seed production (1944-1960) under a mean rainfall threshold, and a period of 49 years (1935-1983) without

seed production if the threshold is 110% of average rainfall. If the threshold is as low as 65% (i.e. just exceeding that of 2007) then reproduction may occur in as many as 60% of years with 2 years being the longest run of consecutive years with reproductive failure.

This modelling does not account for possible effects of the seasonal distribution of rainfall (e.g. cyclonic summer rainfall may not assist in production of fruits if the following winter is dry), nor the possibility that inflorescence production and seed production have different minimum rainfall requirements.

**Summary**

- *Darwinia masonii* seed production is moderately low, varying between years from 9 to 59 seeds per plant in mature populations.
- Variation in production results from (in declining order of importance) variation in inflorescence production per flowering plant, seed predation rate, % of plants flowering, and % of fruits containing seed.
- *Lepidosperma gibsonii* seed production is limited by a requirement for sufficient rainfall in consecutive years. The amount of this rainfall is unknown but appears to lie in the range of 65-110% of the average. Applying these thresholds to the Ninghan rainfall record suggests that the frequency of *L. gibsonii* reproduction may vary between 60% and 22% of years, with likely historic runs of no seed production varying from 2 to 49 years.

**Recommendations:**

- Seed counts should take into account the low number of filled seeds per fruit.
- Seed collection should focus early in the season (November) before moth predation and seed dispersal lead to the loss of most seeds. Later collections will likely contain few uneaten seeds.
- Studies of the identity and habits of the *Darwinia* seed eating moth are recommended.
- Ongoing monitoring of *L. gibsonii* seed production each year, together correlation with rainfall data, will enable refinement of estimates of reproductive frequency.

### 4.3c Seed germination requirements

***Darwinia masonii***

Experiments on 2,700 *Darwinia masonii* stored and X-ray screened seed, collected in three different years (2004, 2007 and 2008) and using a variety of physical and chemical treatments were performed in 2009. Samples included 5 replicates of 10 or 20 seed (depending on availability) treated with smoke water or fresh water, light and dark storage, and excision (seed manually removed from fruit coat), nicking of fruit coats (allows water penetration to seed) or no physical treatment. In this experiment, the highest germination rate, 30%, resulted from dark storage of nicked seed, collected in 2007 and treated with smoke water. Insufficient seed was available to test all combinations, so physical treatments were tested only for dark treatments. In light treatments no germination was observed with $H_2O$, but 3% germinated with smoke (Table 25). In dark treatments, the best germination resulted from nicking or removal of seed coats. For excised seed, $H_2O$ was as effective as smoke water, but in nicked fruits and those with no physical treatment, smoke water had a positive effect. The age of stored seed (up to 5 years old) appeared to have no clear (positive or negative) effect on results.

**Table 25** Percent of fresh *Darwinia masonii* seed germinating from samples stored in with light or in dark conditions, treated with smoke or filtered water (SW v. $H_2O$) and with seed excised, from fruit coats, coats nicked, or no physical treatment (results include different seed batches pooled). nt = not tested.

| | Dark | | Light | |
|---|---|---|---|---|
| | $H_2O$ | SW | $H_2O$ | SW |
| Excised | 18% | 18% | nt | nt |
| Nicked | 4% | 19% | nt | nt |
| None | 0% | 6% | 0% | 3% |
| Grand Total | 3% | 13% | 0% | 3% |

These results suggest that *D. masonii* seeds have both physical and a physiological dormancy processes, the former requiring the removal or breakdown of fruit walls, and the latter indicating a stimulatory effect of smoke chemicals. That smoke had limited effect on germination of fresh seeds also indicates an increased sensitivity to smoke with age. Further details on *D. masonii* germination are given in **4.3d Seed bank demography**.

***Lepidosperma gibsonii***

Due to the absence of seed production in previous years, experiments with fresh *L. gibsonii* seed were delayed until after late 2009. Results from germination experiments with fresh, X-rayed nuts (i.e. known to contain filled

seed) using ± heat × ± smoke/ TC water × ± GA treatments, each with 5 replicates of 25 seeds, resulted in zero germinants. A small number of germinants were observed following burial for 3 and 6 months however (see 4.3d below).

Experiments with *L. gibsonii* seeds manually manipulated under a microscope to remove their external (i.e. fruit wall or nut) casing resulted in levels of germination: up to 60% of excised seeds treated with a heat (100°C) pulse germinated (4.7b see Germplasm storage).

Seed of *Lepidosperma* species are generally difficult to germinate. Recent work at BGPA by Shane Turner and others on other *Lepidosperma* species report the absence of germination without nicking of fruit coats or excision of seed (e.g. Kodym *et al*. 2010, Panaia *et al*. 2009). Turner (unpubl.) also reports a positive role for 80° and 100°C (but not 120°C) heat treatments in germination of previously buried *Lepidosperma leptostachyum* seed. Smoke water and gibberellic acid had independent and interactive positive effects, but maximal germination still did not exceed 25%.

These collected results indicate a physical dormancy process in *Lepidosperma* which may require the break-down of the fruit coat over time through weathering in the soil, and which can be replicated by the somewhat onerous process of seed excision.

**Summary**

- *Darwinia masonii* seed germination is low in experimental treatments on fresh and stored seed, but can be improved by a combination of physical treatments and smoke application.

- *Lepidosperma gibsonii* seed germination remains unsolved, however indications of positive, but still small, effects of seed burial, fruit wall breakdown (or removal), smoke and heat treatments can be derived from related studies and early results from burial experiments.

**Recommendations**

- Large scale production of seedlings of either species via germination of fresh or stored seed is possible, but inefficient, and involves physical manipulation of small seeds for seed coat nicking or removal, or retrieval of seed buried for months or years.

### 4.3d Seed bank demography

The significant soil seedbank germination response observed following experimental fire, described under 'recruitment' in section 4.2 above, indicates the presence of a significant soil seedbank for both species.

An experimental program was established to investigate the longevity and seasonal and longer-term patterns in germinability of seed buried in the soil. The *D. masonii* burial trial commenced in January 2009, and that of *L. gibsonii* as sufficient seed became available a year later. Collected seed was initially x-ray screened to ensure that only filled fruits were used in experiments. These were then counted into nylon mesh bags, with a total of 55 bags of 250 *D. masonii* seeds and 70 bags of 120 *L. gibsonii* seeds created. These were buried in 5 caches each for *D. masonii* and *L. gibsonii*, located on 100m transects running down the north (*D. masonii*) and south (*L. gibsonii*) slopes of Mount Gibson. Soil temperature sensors attached to battery operated data-loggers were placed with each collection which was covered with 2-5 cm of soil. Rocks and litter removed prior to burial was replaced, and a wire cage to exclude vertebrate disturbance was positioned over the top.

The experimental design incorporated provision for retrieval of one bag from each site, i.e. 5 replicate bags per sample period, for 11 (*D. masonii*) / 14 (*L. gibsonii*) sample periods. The retrieval schedule planned was 3 month intervals for two years, followed by annual (*D. masonii*) and biannual (*L. gibsonii*) intervals up to 5 years. This design allows for flexibility in sampling number or interval if early results suggest it may be required.

Prior to treatment, retrieved seeds were x-rayed and scored for internal and external signs of germination, predation or degradation. The five groups of intact seeds (one per retrieval site) were then split into groups of 100 (*D. masonii*) and 25 (*L. gibsonii*) for treatment. On retrieval, as well as (for control samples) at the time of burial (i.e. at time = 0) the five replicate samples were treated, plated out on filter paper in petri dishes and stored in the dark at 15°. Seeds were examined and the number of germinants counted fortnightly until germination ceased at approximately 150 days. *Darwinia masonii* seeds were treated with either smoke water or filtered water, while *L. gibsonii* seeds were treated to a crossed design of smoke water or filtered water and application of heat / no heat. Heat treatment was 100° for 10 minutes. Heat treatments were not applied for *D. masonii* as preliminary tests showed that heat (applied for 10 minutes or 30 minutes) did not enhance germination.

*Darwinia masonii* seed responded to smoke water (SW) at all periods, improving germination by 20-70% over fresh water only (Figure 29a).

Germination was low to negligible with fresh water except in spring (at 9 months) when it peaked at 29%. Smoke-water treated seeds germinated at all times, but at a much higher rate in spring and the second summer. The largest germination response (90%) was to smoke water after 9 months of burial (i.e. in spring). Germinability at 15 months was close to identical with that observed at 3 months and 6 months, suggesting no significant decline in seed viability with age over 2 years, and tight control over the germination process.

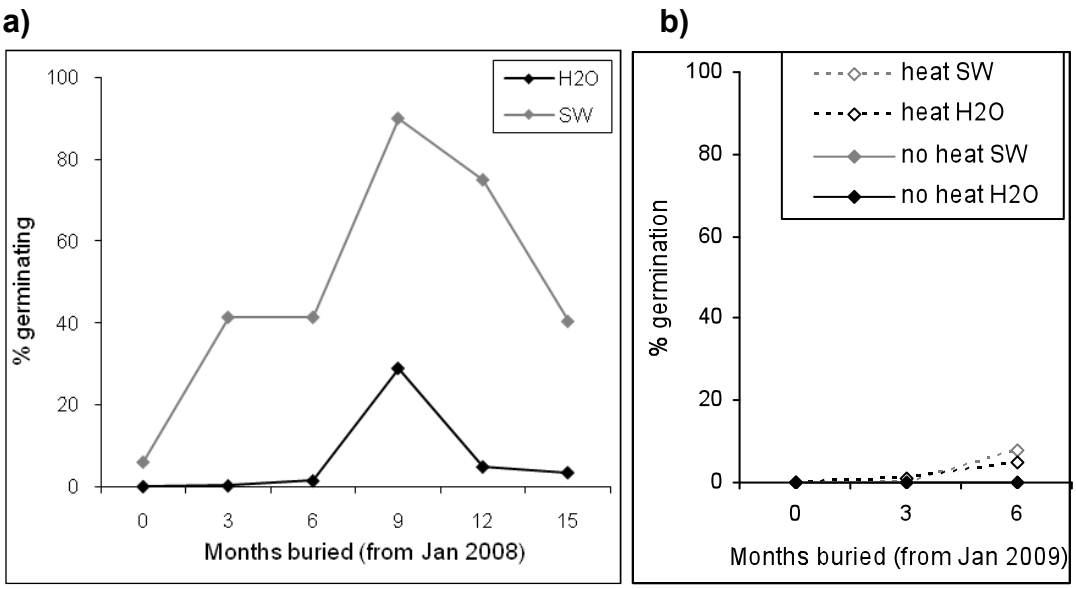



**Figure 29. a)** Germination rate of *Darwinia masonii* seed buried in the field and retrieved after 3-15 months. Results show average of 5 samples of 100 seeds, as well as smoke (SW) and filtered ($H_2O$) water treatments. **b)** Germination rate of *Lepidosperma gibsonii* seed buried in the field and retrieved after 3-6 months. Results show average of 5 samples of 25 seeds, as well as smoke and filtered water treatments crossed with ± heat (100° C for 10 minutes) treatments.

No seeds germinated for *L. gibsonii* in the absence of physical treatment, just one germinated after 3 months of burial (heat + SW treatment) and 16 germinated after 6 months of burial (Figure 29b). These were all in the heat treated samples and represented 8% of the SW and 4.8% of the $H_2O$ only treated samples.

The seasonal pattern observed is common in species with long-lived seedbanks from areas with seasonal climates and indicates that seeds are cycling in and out of dormancy in relation to environmental cues. Soil temperature and moisture are likely to control the induction and loss of dormancy. The incomplete germination with smoke also shows that smoke does not break dormancy, but rather it acts as an additional cue.

**Summary**

- Seed bank trials have been established for both species, and are ongoing. The lack of availability of seed in previous years meant that *Lepidosperma gibsonii* trials had only had 6 months to run by the end of the project.

- Buried seed is still in place with experiments designed to continue for up to 5 years.

- Preliminary results indicate complex germination / dormancy strategies for both species, combining a requirement for physical degradation of the seed coat, environmental (seasonal temperature) cuing – with seeds cycling in and out of dormancy, and heat- and smoke-related physiological responses.

- Germination rates peaked for *D. masonii* at 90% with seed which had been exhumed after 9 months of burial and treated with smoke water

- Smoke water treatments of *L. gibsonii* seed buried for 6 months and exhumed in winter showed a small, but non-zero rate of germination. For this notoriously recalcitrant genus this result is encouraging.

**Recommendations**

- Established seed burial / retrieval trials should continue for at least several further years.

### 4.3e Breeding and mating systems

For most species, self-sustaining populations require both a large pool of genetic variation, and the ability to breed successfully with a wide pool of mates. Patterns of mating determine the level of homozygosity in the next generation, and thus affect reproductive success, fitness of offspring, genetic diversity and genome evolution. Relatively few inbreeding species have evolved mechanisms, or sufficiently purged their genome to withstand the deleterious effects of inbreeding over evolutionary timescales (hundreds of generation).

Knowledge of breeding and mating systems in rare plants is important for several reasons: (1) it gives basic information on the critical factors in maintaining mating patterns and seed production, (2) it gives baseline information which can then be monitored over time to detect changes in population sustainability (e.g. detecting lowered genetic variation in the seed rain before a fire event that might irrevocably kill off diversity not maintained in

the seedbank), and (3) provides information on the critical factors for creating a self-sustaining population in translocation and restoration efforts.

Following Neal & Anderson (2005), Breeding system refers to the physical and physiological aspects of plant mating: (e.g. sex of flowers, relative timing of development of different organs, self-compatibility mechanisms etc). Mating system refers to the relatedness of mating gametes, and spatial relationships of parents (e.g. inbreeding, outcrossing, correlated paternity).

### *Darwinia masonii*

#### Breeding system

Like most other species in Myrtaceae tribe subtribe Chamelaucineae (sensu Rye in press), the flowers of *D. masonii* exhibit *pollen presentation*. This specialised mechanism facilitates more accurate deposition and removal of pollen, or in some cases increase rates of self-fertilisation (for specific discussion of pollen presentation in Myrtaceae see Slater & Beardsell, 1991 and Beardsell et al., 1993). The pollen of *D. masonii* exudes from the anthers while the flower buds are still closed, it then becomes soaked in an oily pollenkitt which is excreted from a terminal gland on the anther. This pollenkitt and pollen attaches to a band of hairs just below the tip of the central style. As the flower opens and the enclosing bracteoles are pushed away, the style rapidly elongates to its full length, carrying the fresh, wet pollen with it just below the apex of the style. The timing of stigmatic receptivity has not been studied in *D. masonii*, however in the related species *Chamelaucium uncinatum*, the stigma is initially small and unreceptive at anthesis, but increases in size and becomes fully receptive 7 days after anthesis. (O'Brien 1996). In other species of *Darwinia* studied at Kings Park, the stigma is also initially unreceptive for many days after anthesis, but the stigma does not enlarge on becoming receptive; the only indication that the stigma has become receptive is a slight "wetting" of the style as a sugar-rich solution is released to simulate germination of pollen tubes. *D. masonii* is almost certainly very similar to other WA *Darwinia* species in its stigmatic development.

Pollen presentation has the potential to be very efficient at depositing and collecting pollen at a single area on a pollinator's body, but also increase the likelihood of *self-pollination* due to the close proximity of pollen to the stigma. An assessment is therefore necessary to determine (1) whether plants can and do self-pollinate, (2) what percentage of inbred seeds are produced, (3) do plants preferentially select outcross pollen, and (4) do outcrossed seeds germinate and survive better than selfed seeds? These factors are critical to

allow accurate population-viability measures to be recorded and modelled; for instance, if most seeds are selfed, but selfed seed survive significantly worse than outcrossed seed, then effective seed production may be far lower than that measured crudely by seed fill rates. These questions are addressed below.

Pollinators: A total of 20 hours (x 2 people) was spent bird watching, initially at 2 hour intervals per day over 3 days, subsequently at times of peak bird activity between 0830 and 1100. Each observation point had a more-or less unrestricted view of 12 or more reproductive *D. masonii* plants. A total of 10 hours was spend watching insects on 1-3 plants at a time, initially in 15-minute blocks at 4-hour intervals over 3 days, subsequently at times of peak insect activity between 0930-1100. Each observation consisted information on: species, time spent feeding, number of plants visited, number of flowers visited per plant and destination after initial visitation.

*Results:*

A total of 26 bird visitations was observed, with all identifications (n=18) of a single species, the White-fronted Honeyeater (*Phylidonyris albifrons*). At least five other species of honeyeater have been observed at Mt Gibson, but none were observed visiting *D. masonii*. White-fronted Honeyeaters landed on the branches of *Darwinia* plants (or rarely the ground) and probed upward into the flower head to reach the copious nectar produced by recently-opened flowers. Birds were observed physically contacting styles. On one occasion a bird was seen vigorously wiping its beak on branches immediately after a visit to *D. masonii*, presumably to remove a build-up of sticky pollenkitt received from styles. Birds fed for 10 seconds to 2.5 minutes at a time, and visited single flowers on single plants, up to numerous flowers on at least 6 plants; most consecutive visits were between neighbouring plants, before flying away out of sight. Pollen longevity is not known, neither are honeyeater movements on larger temporal and spatial scales.

Although native bees and wasps were observed visiting other plant species around *Darwinia* plants, the only insect activity seen on *D. masonii* was very rare (n=2; total of 10 flowers) visitations of introduced honeybees, and one of a large native wasp. Visitations involved bees/wasps attempting to reach the nectar from the base of flower heads, and not attempting to collect the (wet) pollen held on styles [In contrast, numerous bees were observed combing plants of *Calycopeplus collinus* nearby for their dry pollen]. Most attempts by bees / wasps to reach nectar of *D. masonii* failed due to the angle of the head, and the insects usually left without touching the styles. Only twice was an insect (1 bee, 1 wasp) observed to reach the nectar, on a flower head held

laterally and by the insects reaching in from the perimeter past the red bracts, without contacting pollen or the stigma. Only once was a bee observed contacting the style and stigma, during an unsuccessful attempt to squeeze through the mass of styles.

Conclusion: while both insect and bird visitation both occurs, by far the dominant (potential) pollinators are White-Fronted Honeyeaters, with insect visitation at best rare and ineffectual.

Pollinator dependence and inbreeding rate: The effective dispersal of pollen in most plants relies on the activity of pollinators. Some plants, however, have evolved strategies to avoid the need for outcrossing, and instead self. Other plants show a mixed mating system, with the ability to self-pollinate in the absence of pollinators. In this study, the ability of *D. masonii* to produce seed, and the effect of types of pollinators on total seed production was studied.

Sixteen plants in a single population were divided into three groups:

- Complete pollinator exclusion (caged with fine mesh to exclude all insects and birds); N=4.
- Partial exclusion (with 1 cm gap mesh to allow insect pollination but exclude birds); N=4.
- Open pollinated (uncaged); N=8.

Cages were erected to be self supporting and completely enclose plants, but provide minimal shade, and were placed over plants prior to anthesis of the first flowers (Figure 30).

**Figure 30.** Exclusion cages for *D. masonii* pollination study. Left: Bird and insect exclusion, Right: Bird exclusion.

Mature fruits (each fruit contains a sing (rarely two) seeds) were X-rayed in Faxitron X-ray Corporation v1.2 (exposure 21kV for 10 seconds) to determine whether a viable seed had developed. Seeds with filled ovaries (from the enlarged hypocotyl which forms the bulk of the seed in *D. masonii* (Prakash, 1969) were recorded (Figure 4). Seeds that are non-viable just show a cavity. A percentage of viable seeds out of the subset X-rayed were determined.

Mating system parameters was estimated using the MLTR program v3.2 (Ritland, 2002). MLTR estimates from progeny arrays the following parameters: 1) multilocus population outcrossing rate, 2) bi-parental inbreeding rate (mating among relatives) and 3) correlated paternity (fraction of siblings that share the same father).

Results: When all pollinators were completely excluded, seed set (6.6%) was significantly greater than zero ($P<0.05$; Figure 31). When birds were excluded but insects were allowed access to the plants, there was an increase of seed set to 14.8%, although this was not significantly greater than that following all pollinator exclusion ($P>0.05$). In contrast, plants given full access to pollinator showed a significant increase (23%, $P<0.05$) in seed set compared to complete pollinator exclusion; this result was however not significant when compared to the treatment excluding birds only (allowing insects).

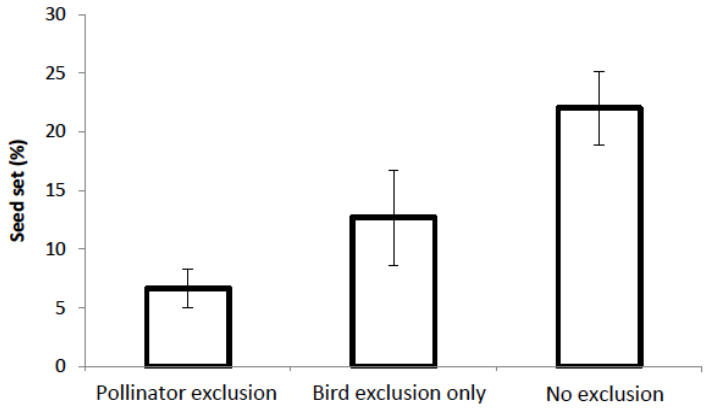



**Figure 31.** Percentage of flowers with filled seed from D. masonii plants allowed access to different classes of pollinators. In the control (no exclusion), seed set was relatively high (23%), compared to caged plants which excluded birds. The caged plants that excluded all pollinators (birds and insects) had the lowest seed set (7%), while the plants caged to exclude birds but not insects had an intermediate seed-set (13%). This data suggests that (1) plants can set a lowered level of self seed in the absence of pollinators, (2) that birds are significant pollinators, almost doubling the seed-fill rate compared to insect-only pollination, and (3) insect activity appears to have a weaker contribution (however the last result is not significantly different from zero).

Conclusion: *D. masonii* is able to self-pollinate at a low rate (6.6%) in the absence of pollinators, however pollinator activity significantly increases seed set. The study was not powerful enough to unambiguously separate the actions of pollinator classes, however the trend agrees well with pollinator observations: rare insect visitation increases the outcrossing rate (and seed set), however birds are much more effective pollinators and more common visitors, resulting in a higher seed set.

These results were further corroborated by an assessment of mating system parameters using MLTR (Ritland, 2002). Assignment of paternity using microsatellite genotypes (comparing maternal-only markers vs presence of non-maternal and therefore outcrossed markers) showed a multilocus outcrossing rate (tm) for the open pollinated plants (control) of 0.57 (0.09) (Table 26). This was greatly reduced, as expected, when all pollinators were excluded (tm = 0.17 ± 0.17, i.e. not significantly different from zero, as expected for complete selfing). The presence of insect pollinators only however increased the multilocus outcrossing rate to intermediate levels (tm = 0.45 ± 0.19; $P<0.05$), suggesting that insects can supply some pollen dispersal service in the absence of birds.

**Table 26.** Mating system parameters for pollinator exclusion experiment in *Darwinia masonii*. Multilocus outcrossing rate (tm), bi-parental inbreeding rate (tm-ts), and correlated paternity (rp) were estimated using MLTR (Ritland, 2002).

| Treatment | tm (SD) | tm – ts (SD) | rp (SD) |
|---|---|---|---|
| Complete exclusion | 0.17 (0.17) | 0.08 (0.03) | -0.16 (0.71) |
| Bird exclusion | 0.45 (0.19) | 0.14 (0.04) | 0.32 (0.43) |
| Control | 0.57 (0.09) | 0.03 (0.02) | 0.09 (0.12) |

Assessment of pollen limitation: The benefits of outcross mating over selfing can be expressed at several stages of development, including differential pollen germination, pollen tube growth rates, pollen tube growth in the style, fertilisation success (all pre-zygotic barriers to selfing), differential embryo development (in this case 2 ovules, usually only 1 develops), differential seed ripening, germination rate, seedling emergence, seedling survival and adult reproductive capacity (post-zygotic barriers). In this study we examined the effect of self vs outcross pollen up to seed maturation, by supplementing pollen over and above that received by plants from normal vectors. The three treatments were:

- Open pollinated plants with no supplemented pollen (control)
- Supplemented pollen from a known outcrossed plant, to determine whether there is an increase in reproductive success (seed fill rate)

over and above that observed from natural pollination – ie. is fertilisation *pollen limited* through scarcity of pollinators?

- Supplemented self-pollen (from other flowers on the same plant) to determine whether any observed increase in seed production is the result of *any* pollen limitation (e.g. physical or temporal separation of self-pollen transfer between the style hairs and the stigma), or whether it is *outcross-pollen* limited, implying pollen source is the controlling variable

Results: There was a significant increase of average percentage seed set over the control when outcross (+external) pollen was introduced but not when self-pollen was introduced (Figure 32). An ANOVA test showed $P<0.05$ when comparing no extra pollen (control) and external source of pollen. However, there is no significance increase of seed set when pollen was introduced from the same plant (+self pollen) compared to a control group.

Conclusion: Outcross pollen provides a significant improvement in seed-set rates over self-pollen; the addition of self pollen alone does not increase seed fill rates, suggesting that pollen presented near the style is able to self-fertilise plants effectively. The presence of external pollen, however implies a selection mechanism for outcross pollen – i.e. *D. masonii* is capable of selfing but is *preferentially outcrossing*, the same pattern reported in many eucalypt species.

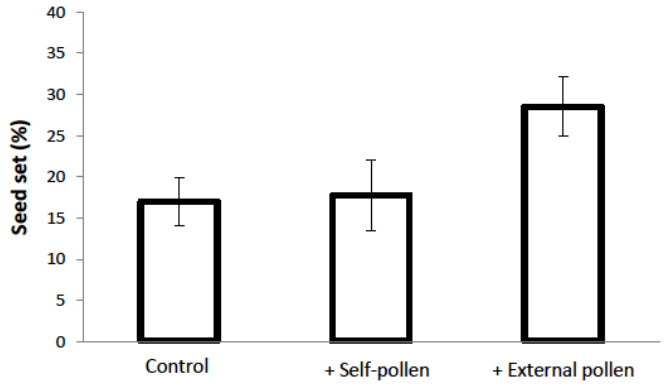



**Figure 32.** Seed fill rates (% of flowers with filled ovary cavity) when given access to natural pollinators (control), supplemented with self-pollen, and supplemented with outcross pollen.

**Genetic diversity at different stages of the lifecycle:**

Selfing is expected to lower the genetic diversity (especially observed heterozygosity and Fixation indices) of offspring relative to their parents. If left unchecked, this will result in a gradual decrease in genetic diversity, and loss

of alleles until populations become almost uniform in genotype. Selection against homozygotes at different developmental stages can however result in maintenance of genetic diversity in the face of inbreeding.

We assessed genetic diversity at three stages of the lifecycle of *D. masonii*: adults, seeds and seedlings, by genotyping using microsatellite markers. Due to access constraints and the need for an experimental fire to generate seedlings under selection for their environment, two separate populations had to be used, (1) the adults and seedbank in the experimental burn are on Extension Hill, and (2) adults and their seed progeny in the Mt Gibson South population. A total of 220 adults and 113 seeds were analysed from Mt Gibson South, while a total of 77 adults and 146 seedlings were analysed from the Extension Hill experimental burn site.

As expected from the presence of inbreeding in *D. masonii*, seeds display reduced observed heterozygosity (Ho, table 27) compared to their parents (although the result is not statistically significant), and increased Fixation Index (a measure of homozygosity). Assuming both breeding system and selection processes are common between the two sites, the fact that parameters for seedlings are close to parent values is evidence for selection against inbred seeds / homozygotes, possibly through the action of lethal alleles.

**Table 27.** Comparative average diversity estimates for 2 adult populations of *D. masonii*, and their respective offspring: Pre-fire adults and post-fire seedling recruits at Extension Hill, and Adults and their seeds from Extension Hill south. Diversity measures are I (Information index), Ho (observed heterozygosity, He expected heterozygosity, and F fixation index; all values are means ± standard error). Seeds show a distinct decrease in observed heterozygosity and an increase in Fixation index (consistent with a percentage of inbreeding), while seedlings are more similar to adults, suggesting selection against inbred seeds in this species.

| **Averages:** | **I** | **Ho** | **He** | **F** |
|---|---|---|---|---|
| EH Adults pre-burn | 1.245 ± 0.290 | 0.557 ± 0.145 | 0.601 ± 0.128 | 0.106 ± 0.106 |
| EH post-fire seedlings | 1.251 ± 0.287 | 0.515 ± 0.133 | 0.597 ± 0.124 | 0.139 ± 0.099 |
| MGS Adults | 1.309 ± 0.307 | 0.571 ± 0.083 | 0.619 ± 0.094 | 0.070 ± 0.021 |
| MGS seeds | 1.209 ± 0.306 | 0.479 ± 0.095 | 0.587 ± 0.113 | 0.154 ± 0.047 |

A mating system in which plants can inbreed, but select against inbreed seed, ultimately producing mostly outcrossed offspring is termed *preferential*

*outcrossing*, and is known to be the dominant system in *Eucalyptus* (also a member of the family Myrtaceae, like *Darwinia*) (House 1997).

**Summary:**

- *D. masonii* is predominantly pollinated by a single species of bird, the White-fronted Honeyeater.
- *D. masonii* is capable of selfing but selection for outcrossed seeds occurs at several levels, greatly reducing the number adult plants resulting from self-pollination, and the production of outcrossed seed is therefore a critical requirement for maintaining a self-sustaining population.
- Any restoration or translocation efforts must include the community context for *D. masonii*, especially in regard to ensuring adequate habitat for White-fronted Honeyeaters.

***Lepidosperma gibsonii***

*Lepidosperma gibsonii* is wind pollinated, and so does not have complex pollinator interactions as seen in *D. masonii*.

The mating system in *L. gibsonii* was investigated by sampling inflorescences from 12 plants and collecting the seed produced (total 48 seedlings). Embryos were extracted from seed using the protocol presented here, and left to grow into small seedlings on agar. Seedlings were then removed, DNA extracted, and genotyped using 11 microsatellite loci. Assignment of paternity using microsatellite genotypes (comparing maternal-only markers vs presence of non-maternal and therefore outcrossed markers) showed a multilocus outcrossing rate (tm) for the open pollinated plants of 91.7 %, demonstrating a very high rate of outcrossing compared to selfing, as expected for a wind-pollinated species, and as expected by the high genetic diversity and lower level of population structure observed in *L. gibsonii* (see section 4.1).

Population size and weather conditions are the likely factors affecting pollination success. Further research on the effect of population size (and therefore pollen abundance) on inbreeding rate would be beneficial.

**Summary:**

- *L. gibsonii* appears to have widespread, wind-assisted pollen dispersal and high rate of outcrossing.

### 4.3f Dispersal

Studies of dispersal took two forms: 1) inferences of possible seed dispersal patterns, vectors and distances from observations and experimental studies of dispersal agents and 2) measurements of patterns of actual dispersal of genetic material in both pollen and seeds, by using molecular techniques to identify the parents of seedlings observed following experimental fire.

***Darwinia masonii***

**Pollen and seed dispersal**

Pollen dispersal was studied by parental assignment of seed genotypes with known mothers to determine their most likely father (pollen donor). The program CERVUS (Kalinowski et al. 2007) was used to assign paternity to genotyped seeds collected from known, genotyped mother plants. A total of 200 seeds were genotyped and the most likely sire estimated from among 200 possible surrounding adult plants using likelihood assignment techniques. Effective Seed dispersal was studied by genetic assignment of seedlings within the surrounding pool of prospective parents. Since *D. masonii* seeds only rarely germinate in the absence of fire, an experimental fire was carried out in an area within the approved clearing footprint that contained a population of reproductively mature *D. masonii* (likely dating from the 1969 fire). Since adult plants are typically killed by fire, all adult plants in this population were genotyped prior to burning. The experimental fire was carried out in May 2009, just prior to the onset of winter rainfall, and seedlings were sampled at the end of spring, i.e. after the first season of growth but prior to the first summer. A total of 80 adult plants were genotyped, and a total of 230 seedlings were recovered and genotyped. Only the lowest leaves (senescing cotyledons) were sampled in order to track seedling survival (and genetic correlates with survival) through time. The program CERVUS (Kalinowski et al. 2007) was used to select the most likely parents (maternal and paternal) from among the 80 adult plants present before the fire. Results of this work are being prepared for publication.

**Identity and behaviour of seed dispersal agents**

Fruits of *Darwinia* species from NSW are reported by Auld (2009) as being dispersed by ants, and studies at Extension Hill confirm this behaviour with respect to *D. masonii*. Seed removal by ants was assessed in a baiting experiment, in which 14 piles of 5 *D. masonii* seed were observed between 9

am and 3 pm on December 2 2009, with seeds in baiting stations refreshed if any were seen to have been removed. The number and time of seed removal events was recorded and specimens of ant species observed removing seed were collected for identification (by Brian Hederick, Curtin University). The foraging behaviour by *R. violacea* ants (previously reported to be a key seed-dispersing species in SW WA; Gove *et al*. 2007) was examined on Extension Hill south (in December 2007 and May 2009). Foraging distances were assessed by offering randomly observed individuals food morsels (muesli bar fragments) and recording the distance back to their nest. Finally, to identify the interest of ants in *Darwinia* seeds, individually marked, weighed and photographed fruits were offered to captive *R. violacea* ants, which quickly removed the fruits below ground, but then later returned them to the surface. Returned seeds were rephotographed and weighed.

Six species of ant were observed removing *D. masonii* seeds in December 2009: *Iridomyrmex chasei*, *I. gracilis minor*, *Melophorus turneri perthensis*, *Rhytidoponera crassinoda*, *R. metallica* and *R. violacea*. Seed was removed from all 14 observed stations with an average of between 0.3 and 7.3 removals per station per hour, although at one station 41 seed were removed in a 1 hour period, including 18 in one 10 minute period, by *M. turneri perthenis* to a nest 2.5 m away.

A total of 30 *R. violacea* foraging distance observations were made at Extension Hill these indicate an average foraging distance of 3.7 m and a maximum of 10.8 m.

Auld (2009) suggests that ant dispersal of *Darwinia* fruits results from the attractiveness of *Darwinia* petals, however observations of *D. masonii* fruits collected and then returned to the surface by captive *R. violacea* ants with intact petals contradicts this idea. Instead, we suggest that ants are attracted to the highly concentrated but still-liquid nectar which coats the outside of *D. masonii* fruits. After processing by ants fruits weighed 10% less and had intact petals (n= 12 fruits). Before and after photographs also clearly show the removal of the external liquid coating.

Most offered fruits were disposed above ground by captive *R. violacea* ants, and 12 of 30 *R. violacea* nests discovered in the field had collections of up to 50 *D. masonii* fruits scattered at their entrance. However two observations of *D. masonii* seedlings emerging in groups of 4-6 individuals from buried ant garbage chambers at Extension Hill and Mt Gibson confirms the role of ants in the effective dispersal (and burial) of seed. It is possible that this dispersal process is responsible for the phenomenon of two or more *D. masonii*

individuals growing in immediate proximity, with stems frequently observed abutting at their base.

**Figure 33** An ant (*Melophorus turneri*) depositing fruits of *Darwinia masonii* on the soil surface close to a nest (left). (right) Four *D. masonii* seedlings germinating from a below-ground garbage chamber – note other seeds and parts of insects, including ants (identified as *Rhytidoponera violacea*).

### *Lepidosperma gibsonii*

#### Pollen dispersal

Population genetic analyses of *Lepidosperma gibsonii* have shown that pollen dispersal must be extensive across all populations within the Mt Gibson area, due to the extremely low genetic differentiation between populations. This is almost certainly due to wind-dispersed pollen in this species (confirmed by field observations of dry pollen released in clouds at anthesis).

#### Seed dispersal

The small size, and abiotic dispersal vectors of *L. gibsonii* seed means that their dispersal is difficult to physically track – poor seed production also excluded the possibility of dispersal experiments which would be costly to limited seed stocks. The best method that could be constructed to measure seed dispersal was mapping actual dispersal distance by assignment of seedling genotype to its source plant. Since *L. gibsonii* seed only germinate after fire, this experiment made use of the May 2009 experimental fire to stimulate germination of seedlings. Three 5 x 5 m quadrats were marked out prior to burning, within which all adult plants were mapped, and then sampled and genotyped with 10 microsatellite loci. Plants were sampled exhaustively, with up to 11 samples per clump, since *Lepidosperma* clumps were previously shown to contain multiple intertwined clonal genotypes within larger clumps.

The experimental fire was carried out just prior to the onset of winter rainfall, and seedlings sampled at the end of spring, i.e. after the first season of growth but prior to the first summer. A total of 200 seedlings was collected and assigned to their most likely parents using the program CERVUS (Kalinowski et al. 2007). Results of this work are being prepared for publication.

**Identity of seed dispersal agents**

Insufficient seed was available for comprehensive studies of dispersal in *Lepidosperma gibsonii*; however seed have no apparent external dispersal adaptations. A small sample of fruits offered to captive seed-dispersing ants (*Rhytidoponera violacea*) collected from Extension Hill did not result in fruits been removed. The location of *L. gibsonii* seedlings, concentrated below rocks, in spouts and flow points on rocky slopes suggest that at least some seed is moved and concentrated by gravity (perhaps stimulated by scratching birds – e.g. Mallee Fowl), or flowing water.

**Summary**

- Effective pollen and seed dispersal distances were determined for both species.
- Experiments confirm the key role of ants in dispersal of *D. masonii* seed. Ants appear likely to collect and move nearly all fallen *D. masonii* seed, concentrating undamaged seeds in below-ground garbage chambers or surficial garbage piles. Predation of seeds by ants was not recorded.
- Observation suggests that water may be the primary dispersal vector of *L. gibsonii* seed.

**Recommendations**

- If collection of seed of *D. masonii* or *L. gibsonii* from the ground is to be attempted, allowance should be made for their dispersal processes i.e. – specifically where seeds might be concentrated.

## 4.4 PVA MODELLING

Population viability analysis (PVA) modelling of demographic processes in both species was proposed to assess population growth rates, and population (and species) extinction likelihoods, taking into account impacts of the loss or augmentation of populations, as well as variation in climate and fire regimes. This modelling would be based on demographic data derived from the demography and seed longevity programs (incorporating plant survival,

growth, seed production, seed bank dynamics, fire response). The input data is required to be representative of the range of annual variation in each trait and associated with measured variation in climate (e.g. rainfall). With such data it is possible to model variation in population behaviour in relation to realistic climate data variation – manipulating the frequency or sequence of years of different types. The impact of fire can similarly be modelled by inserting fire years at varying intervals, varying the age and number of populations burnt. Soil seedbanks are an essential part of population dynamics of both DRF species, but add considerable complexity to models, and require accurate data to populate them.

The patterns of annual variation demonstrated through the period of the survey indicate that the data collected is not sufficient to construct worthwhile PVA analyses for either species. A greater number of years of data are required in order to capture sufficient natural variability for such models to make sense.

Examples of key processes inadequately represented by the three-year survey period include: growth rates of older *D. masonii* plants - which averaged negative growth; *L. gibsonii* seed production which occurred in only one of four observation years; and episodic mortality of *D. masonii* adults as observed in 2010. The longevity of seed in soil seed-banks of both species is equally important. Clearly *D. masonii* growth rates are not negative in the long term, the sample years have not captured anything like the mean rate of growth. Similarly it is unreasonable to assume that *L. gibsonii* reproduction occurs precisely once every three years. PVA modelling cannot be reliable without reasonable values of these (and other) parameters, including reliable estimates of both rates averages and variability (including correlates of this variability). It is clear that a longer period of sampling is required before confidence in the values for these two parameters (and many others) would be sufficient. For *L. gibsonii* two or three seasons with effective reproduction, and for *D. masonii*, enough years to give an average rate of plant growth that is at least positive, and ideally not dissimilar to the long term average derived tentatively from analysis of population structures. Soil seed-bank seed longevity is currently being examined in a program that was designed to monitor survival for ~5 years. For *L. gibsonii* this still has 4 years to run and for both species even a five year sample period may not fully indicate seed bank longevity. These complexities are inherent in species with slow and / or episodic growth dynamics, which are unfortunately common in semi-arid systems.

Without such data, PVA could be performed, but its results would be unreliable, unrealistic and likely unreasonable.

**Summary:**

- This component is incomplete due to the scale of annual variation in key demographic parameters relative to the project's running period.

**Recommendations:**

- Continued monitoring of plants in permanent plots and maintenance of seed burial experiments, including attention to regularity and timing of monitoring and adequate quality control and management and storage of data until confidence in key demographic parameters is confirmed and PVA can be performed.

## 4.5 ENVIRONMENTAL INTERACTIONS AND PLANT HEALTH

### 4.5a Abiotic associations

Two approaches to determining environmental associations of *D. masonii* and *L. gibsonii* were taken, one, an analysis of site factors assessed at locations where plants were surveyed, and the other modelling of species distributions against spatially mapped environmental data.

**Site factors** assessed at each demographic and physiological monitoring site are listed in Table 28. Canopy openness was assed via analysis of fish-eye photographs taken at 3 locations in each plot using a 180° angle lens adaptor to take full-sky hemispherical images (e.g. Figure 34). The camera was mounted on a tripod at 40 cm above the ground, levelled with a bubble level with the lens pointing directly upwards and oriented with north at the top of the image. Images were analysed using Gap Light Analyser (v 2.0, 1999) image analysis software for % canopy openness – the proportion of the vertical hemisphere that is not obscured by plants or surrounding hills. Site surface attributes estimated on the ground included % surface area covered by soil crusts (e.g. lichens), litter, gravels, outcropping rock, etc. and mean vegetation canopy height. Altitude, slope and curvature, together with solar radiation receipt were derived from a 1 m interval contour map (see this section below for details). Soils were collected from each site and analysed for pH, electrical conductivity, organic content and major plant minerals and other elements at the WA Chemistry Centre.

Several differences were determined between sites with *D. masonii* and sites with *L. gibsonii* (Table 28). Almost all soil elements analysed were less abundant in *D. masonii* than *L. gibsonii* sites, but only Ca, K and Ni were

significantly lower. Sites with *D. masonii* also had significantly lower slopes and significantly greater solar radiation receipt at several times in the year, as well as large, but non-significant differences suggesting greater canopy openness and rock cover relative to sites with *L. gibsonii*. These results suggest that *D. masonii* typically occurs in flatter, hotter (drier), rockier and more open locations with poorer soils than does *L. gibsonii*.

**Figure 34.** Examples of hemispheric images used in estimation of % canopy openness at each site. Note the horizon visible around much of the perimeter of the right-hand image.

**Table 28.** Site factors assessed for demography survey, physiology survey and translocation sites, mean ± SE (n) within localities with *D. masonii*, *L. gibsonii* or neither ( translocation and comparator species physiology sites). Asterisks indicate significant differences between *L. gibsonii* and *D. masonii*: sites * <0.005, ** <0.0005. To minimise type I errors due to the large number of tests an α of 0.005 is employed. Near-significant tests, *P* <0.05 are indicated '+'.

| species | units | *L. gibsonii* sites | **sig.** | *D. masonii* sites | neither |
|---|---|---|---|---|---|
| canopy openness | % | 62 ± 4 (7) | + | 74 ± 4 (11) | |
| crust cover | % | 13 ± 7 (10) | | 6 ± 3 (12) | |
| gravel cover | % | 32 ± 5 (11) | | 27 ± 5 (15) | |
| rock cover | % | 28 ± 6 (11) | | 44 ± 6 (16) | |
| bare soil | % | 22 ± 3 (11) | | 19 ± 4 (16) | |
| litter cover | % | 20 ± 6 (11) | | 19 ± 4 (16) | |
| debris >1cm cover | % | 1.4 ± 0.5 (11) | | 1.8 ± 0.3 (16) | |
| vegetation cover | % | 43 ± 5 (11) | | 36 ± 3 (16) | |
| vegetation height | m | 2.5 ± 0.5 (11) | | 2.7 ± 0.5 (15) | |
| altitude | m asl | 385 ± 7 (13) | | 385 ± 7 (19) | 377 ± 6 (15) |
| slope | ° | 16.7 ± 1.9 (13) | ** | 9.4 ± 0.9 (19) | 7.9 ± 1.2 (15) |
| curvature-profile | concave + | 1.44 ± 0.59 (13) | + | 0.01 ± 0.26 (19) | 0.12 ± 0.11 (15) |
| curvature-plan | convex - | 1.36 ± 0.72 (13) | | -0.54 ± 0.44 (19) | 0.24 ± 0.19 (15) |
| Solar Radiation | | | | | |
| July 10 am | $w.m^{-2}.hr^{-1}$ | 0.33 ± 0.05 (13) | ** | 0.83 ± 0.05 (19) | 0.69 ± 0.04 (16) |
| July 12 pm | $w.m^{-2}.hr^{-1}$ | 0.91 ± 0.06 (13) | | 0.95 ± 0.03 (19) | 0.93 ± 0.02 (16) |
| July 2 pm | $w.m^{-2}.hr^{-1}$ | 0.59 ± 0.05 (13) | ** | 0.82 ± 0.03 (19) | 0.79 ± 0.03 (16) |
| July 4 pm | $w.m^{-2}.hr^{-1}$ | 0.24 ± 0.04 (13) | | 0.33 ± 0.04 (19) | 0.27 ± 0.02 (16) |
| Equinox 10 am | $w.m^{-2}.hr^{-1}$ | 0.67 ± 0.05 (13) | ** | 1.11 ± 0.05 (19) | 1.00 ± 0.03 (16) |
| Equinox 12 pm | $w.m^{-2}.hr^{-1}$ | 0.78 ± 0.05 (13) | ** | 1.12 ± 0.02 (19) | 1.08 ± 0.03 (16) |
| Equinox 2 pm | $w.m^{-2}.hr^{-1}$ | 0.96 ± 0.04 (13) | | 0.97 ± 0.03 (19) | 1.07 ± 0.02 (16) |
| Equinox 4 pm | $w.m^{-2}.hr^{-1}$ | 0.74 ± 0.05 (13) | | 0.67 ± 0.05 (19) | 0.76 ± 0.02 (16) |
| December 10 am | $w.m^{-2}.hr^{-1}$ | 0.99 ± 0.06 (13) | + | 1.17 ± 0.03 (19) | 1.07 ± 0.02 (16) |
| December 12 pm | $w.m^{-2}.hr^{-1}$ | 0.79 ± 0.04 (13) | * | 0.89 ± 0.01 (19) | 0.90 ± 0.01 (16) |
| December 2 pm | $w.m^{-2}.hr^{-1}$ | 1.09 ± 0.03 (13) | | 1.03 ± 0.04 (19) | 1.13 ± 0.01 (16) |
| December 4 pm | $w.m^{-2}.hr^{-1}$ | 1.07 ± 0.05 (13) | + | 0.84 ± 0.05 (19) | 1.01 ± 0.02 (16) |
| EC | (1:5) mS/m | 7.6 ± 1.2 (12) | | 5.5 ± 0.5 (18) | 6.6 ± 0.9 (20) |
| pH | ($CaCl_2$) | 5.1 ± 0.2 (12) | | 4.9 ± 0.1 (18) | 4.8 ± 0.1 (20) |
| OrgC | (W/B) % | 3.2 ± 0.3 (12) | + | 2.4 ± 0.2 (18) | 1.5 ± 0.2 (20) |
| N | (total) % | 0.15 ± 0.01 (12) | | 0.11 ± 0.01 (18) | 0.08 ± 0.01 (20) |
| P | PRI mL/g | 41 ± 5 (12) | | 55 ± 6 (18) | 44 ± 8 (20) |
| B | mg/kg | 0.91 ± 0.08 (12) | | 1.01 ± 0.05 (18) | 0.58 ± 0.09 (20) |
| Ca | mg/kg | 1025 ± 169 (12) | * | 578 ± 53 (18) | 525 ± 79 (20) |
| Co | mg/kg | 0.17 ± 0.02 (12) | | 0.19 ± 0.02 (18) | 0.23 ± 0.06 (20) |
| Cu | mg/kg | 1.33 ± 0.13 (12) | | 1.38 ± 0.12 (18) | 0.89 ± 0.11 (20) |
| Fe | mg/kg | 98 ± 21 (12) | + | 59 ± 5 (18) | 63 ± 5 (20) |
| K | mg/kg | 151 ± 11 (12) | * | 108 ± 8 (18) | 86 ± 8 (20) |
| Mg | mg/kg | 171 ± 17 (12) | + | 110 ± 13 (18) | 67 ± 10 (20) |
| Mn | mg/kg | 72 ± 10 (12) | | 68 ± 5 (18) | 30 ± 4 (20) |
| Na | mg/kg | 34 ± 6 (12) | | 24 ± 3 (18) | 15 ± 2 (20) |
| Ni | mg/kg | 0.38 ± 0.05 (12) | * | 0.20 ± 0.03 (18) | 0.2 ± 0.02 (20) |
| S | mg/kg | 12.7 ± 1.1 (12) | | 15.4 ± 1.6 (18) | 15.9 ± 1.6 (20) |
| Zn | mg/kg | 1.5 ± 0.2 (12) | + | 1.0 ± 0.1 (18) | 5.0 ± 2.3 (20) |
| Pb | mg/kg | 0.79 ± 0.08 (12) | | 0.84 ± 0.04 (18) | 1.19 ± 0.21 (20) |

**Modelling of species distributions** was undertaken using presence records from our own data, together with that of consultant's surveys (ATA 2004, 2006) and some provided from Extension Hill Pty Ltd. These data were combined into a single GIS layer totalling 2534 presence records for *D. masonii* and 912 for *L. gibsonii*. Variation in the numerical resolution represented by the *L. gibsonii* data was extreme, with many location records representing single plants, other representing several or many plants, and a small number representing several thousand individuals each. This data was therefore transformed to a 20m grid, where a single point was located on the grid if one or more plants were recorded within the surrounding 20×20m area. Large populations delineated with two or more point on their margins only were extrapolated appropriately to include more grid points.

Models were constructed using MaxEnt software (V3.3.1; Phillips *et al*. 2006, 2008) which compares environmental data for points where species presences are recorded with equivalent environmental data a large sample (10,000 in this case) of randomly selected 'background' points from the sampled landscape. The MaxEnt routine then select the simplest set of transformations and interactions of the environmental layer data that provide a best fit to the recorded localities. This can then be reprojected onto the spatial maps of the environmental data to produce a map of presence likelihoods. Other MaxEnt outputs include response curves for the model, which show how modelled presence likelihoods change with each environmental variable, and a table indicating the relative significance of each variable to the total model fit. Finally, model fit is tested using AUC / ROC statistics. MaxEnt is increasingly used in ecological research and studies comparing this and other approaches generally find the performance of MaxEnt to be among the best, and often actually the best approach (e.g. Elith *et al*. 2006).

The environmental layer data employed in this study were derived from three sources: Mt Gibson Iron Deposit Geological Plan (Pickands 1967) for geology, satellite and air photo imagery from 1969 to 2007 for fire history (see Figure 10 and Figure 11 for the derived fire history), and the 1m interval contour map available from the region received from Extension Hill. A number of parameters were derived from the contour data – Solar radiation receipt, Aspect, Slope, Curvature, and Elevation – these were calculated (by Sauter Geological consulting) with a 5 m horizontal resolution. Solar radiation (SR) was calculated (following Coleman *et al*. 2009) for the specific latitude of the site on three specified dates (solar equinox and the winter and summer solstices), and for four times on these days (10 am, 12, 2 and 4pm). SR results take into account site shading from nearby topography, assume a constant solar influx and are expressed in $w.m^{-2}.hr^{-1}$. Slope, aspect and

curvature were calculated from the 1m contour data in mapinfo's Discover>Surfaces utility.

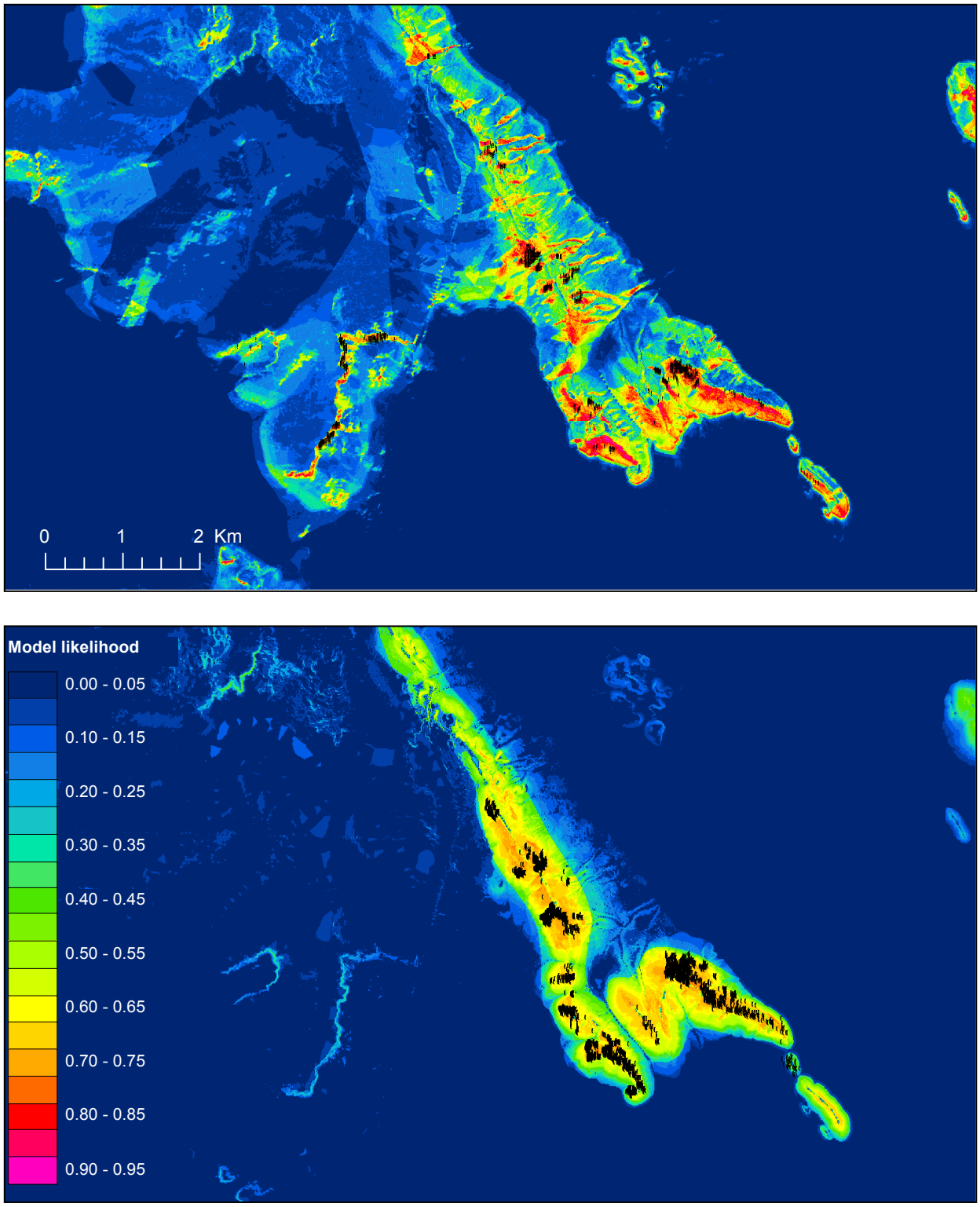



**Figure 35** Maxent model outputs showing probabilities of presence (blue = low, red = high) for *Lepidosperma gibsonii* (top) and *Darwinia masonii*. Black dots indicate known localities.

A breakdown of parameters contributing to model predictions shows that, for *L. gibsonii*, winter 2 pm solar radiation contributed to 40% of the predictive model, with elevation and slope contributing most of the remainder (Table 29). For *Darwinia masonii*, slope alone makes an 80% relative contribution to model predictions, with elevation, geology and summer midday SR making up most of the rest. Fire history since 1969 did not contribute to model predictions.

Models for both species predicted their respective distributions well (AUC = 0.988 for both *D. masonii* and 0.98 for *L. gibsonii* species: the maximum possible value = 1). Models predicted a detailed pattern of presence probabilities for *L. gibsonii*, with many small areas identified with a >90% likelihood of presence, but a broader pattern of high (60-75%) probability of occurrence for most of the Mt Gibson range for *D. masonii* (Figure 35). Both models predicted few localities outside of the known range, with the exception of Yandanhoo Hill in the far east.

**Table 29** Estimate of relative contributions of the environmental variables to Maxent models for *Lepidosperma gibsonii* and *Darwinia masonii*.

| ***Lepidosperma gibsonii*** | | ***Darwinia masonii*** | |
|---|---|---|---|
| variable | % contribution | variable | % contribution |
| Winter SR 2pm | 40.3 | slope | 79.5 |
| elevation | 29.5 | elevation | 15.4 |
| slope | 13.6 | geology | 1.7 |
| geology | 4.6 | summer SR noon | 1.4 |
| aspect | 3.3 | fire | 1.0 |
| fire | 2.2 | | |

The response curves from the model output indicate that the association of *L. gibsonii* distribution with SR is a negative one (Figure 36), with probabilities of *L. gibsonii* presence of 80% predicted for areas with <0.4 $w.m^{-2}.hr^{-1}$ and a rapid fall in likelihoods at around 0.7 $w.m^{-2}.hr^{-1}$.

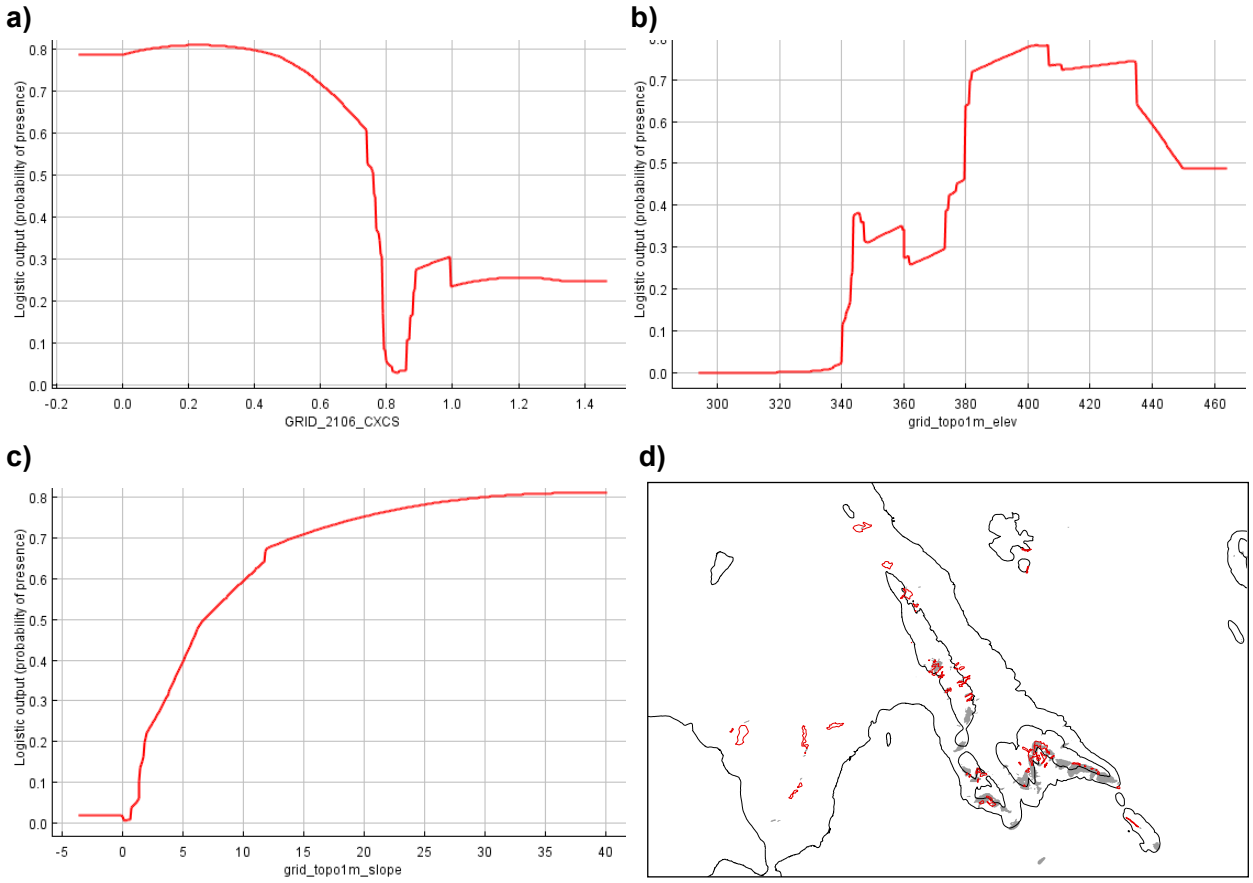



**Figure 36** Response curves of the key variables influencing Maxent model predictions of *Lepidosperma gibsonii* showing presence probability estimates if the shown parameter is used alone as a model input. **a)** Winter 2 pm solar radiation receipt (w.m$^{-2}$.hr$^{-1}$), **b)** elevation (m) and **c)** slope (degrees). **d)** Distribution of *L. gibsonii* (red outline) in relation to winter 2 pm solar radiation <0.6 w.m$^{-2}$.hr$^{-1}$ (grey) and elevation (340 and 380 m contours)

The response curves of the principal environmental parameters predicting *Darwinia masonii* distribution – elevation, slope and geology – suggest that their contribution to the model is solely to select the Mt Gibson range (Figure 37). Slopes over 7-8°, elevation over 380 m and all geology types except for 14 and 99 have an associated probability of 50-60% if considered alone. Geology unit 99 represents areas not covered by the mapping. As mapping focussed on the ridges and slopes of the range, a negative association with this unit effectively identifies the range and foothills. Unit 14 is “White Rock (unclassified, including granite & its group, acidic dyke rocks, feldspar porphyry & meta-sediments phyllitic rock)” this captures the footslopes of the ranges and the saddles between major hills. Thus elevation, slope and geology parameters combine to indicate simply that *D. masonii* is associated with the slopes and ridges of the BIF range.

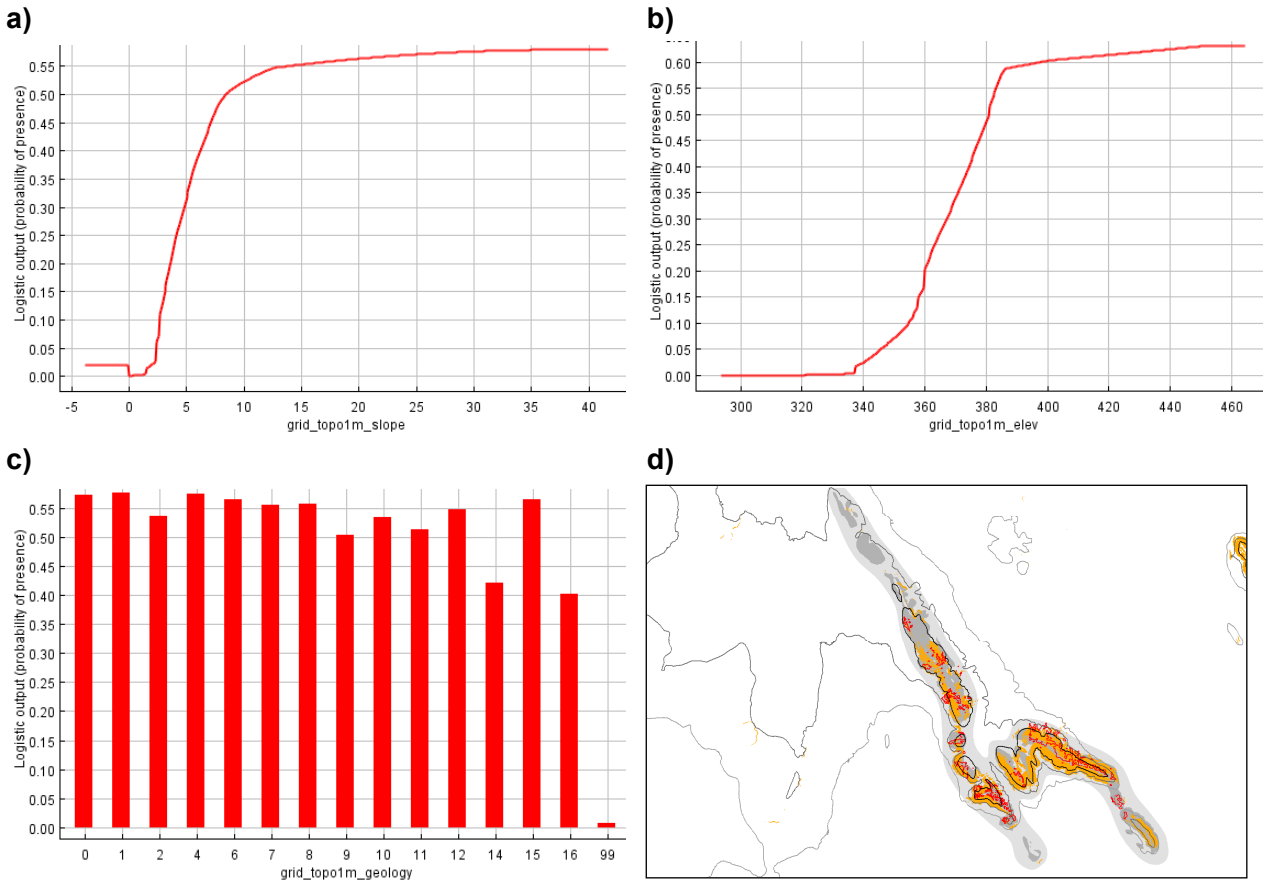



**Figure 37** Response curves of the key variables influencing Maxent model predictions of *Darwinia masonii* showing presence probability estimates if the shown parameter is used alone as a model input. **a)** slope (degrees), **b)** elevation (m) and **c)** geology – see text for codes. **d**) distribution of *D. masonii* (red outline) in relation to slope >12° (orange), elevation (340, 360 and 385 m shown) and geology (white = 99, light grey = 14, all others, dark grey).

## Implications

The maxent models for *D. masonii* and *L. gibsonii* identify the species' respective habitats with differing degrees of detail. The *L. gibsonii* model identifies locations which are the coolest part of the landscape. Low solar radiation means relatively low receipt of light and heat, which have differing implications for plant behaviour and plant environment. Plants require light for photosynthesise but, particularly if deficient in water or nutrients, too much light can damage plant tissues: during summer droughts, damage to plant photosystems from excess sunlight can lead to long-term damage. Heat loads associated with solar radiation receipt can also influence plant physiology, but more importantly, by promoting evaporation, soil moisture availability. Field-based manipulative experiments examining the interactions of heat, soil moisture and photoinhibition and photosystem damage would be required in order to disentangle the physiology reflected in the association of *L. gibsonii* with low radiation areas. However the strength of this association is clear. The

habitat of *D. masonii*, on the other hand, is not so circumscribed and appears to be simply gravelly / rocky iron-rich loams.

*Lepidosperma gibsonii* is already known to occupy many of the areas that it is most strongly predicted to occupy. It is suspected that most of the remaining highly predicted areas will also contain populations if they were to be surveyed. In contrast, *D. masonii* is predicted to occur broadly across the ranges with a high likelihood but not predicted to occur anywhere with a very high likelihood. Many areas where populations are most highly predicted are known to not support *D. masonii* individuals. These results suggest three things. Firstly, that while the factors limiting the distribution of *L. gibsonii* are described by the environmental variables modelled, the distribution *D. masonii* may be limited by factors not included in the model inputs. Unincorporated factors might include attributes of the regolith – soil depth, underlying rock structure, etc – and longer-term fire-regime. Fire history since 1968 was included as a model input but did not contribute to model predictive capacity. On the other hand, it is likely that longer term fire history patterns not captured by the limited temporal coverage of the data may be important. It seems likely that some areas of the Mt Gibson range are more fire-prone than others – rocky open sites may be less able to carry fire and therefore burn less frequently, for instance.

Secondly, potential restoration and translocation areas for *L. gibsonii* need to be low SR and able to maintain higher soil moisture levels than the landscape average, but all such existing locations are likely to be already occupied. For *D. masonii*, models suggest that iron rich gravelly loams seem likely to be all that is required of a suitable translocation or restoration site, and there are many such areas available which are currently unoccupied if translocation was required. However further details of the substrate may still be important to ensure restoration success – for instance it is not known whether the key attributes of such substrates for *D. masonii* survival will be recreated in restoration.

The final implication, therefore, is that restoration trials for each species should include treatments addressing these uncertainties – i.e. shade and moisture for *L. gibsonii* and attributes of soil depth and rockiness for *D. masonii*.

**Summary**

- Species distribution models were constructed for *D. masonii* and *L. gibsonii* using the Maxent technique to assess the association of both species with key environmental variables.

- Models were able to provide good descriptions of the species' respective distributions, and identified different habitat attributes for each, consistent with different observed micro-site distributions of the two species.

- Results have implications – for survey for new populations, selection of potential translocation sites, construction of restoration areas and research into plant interactions with their environments – which are particular each species.

**Recommendations**

- Restoration areas for *L. gibsonii* should be shaped as slopes or gullies with lower radiation receipt.

- Restoration trials for *L. gibsonii* should include treatments varying shade and moisture.

- Mapping of soil or regolith data for the region to refine distribution models to improve understanding and predictions of the habitat and restoration requirements for *D. masonii*

- Restoration areas for *D. masonii* may not require particular topographies, but attention to soil requirements may be important.

- Restoration trials for *D. masonii* should include treatments varying degrees of soil depth and rockiness.

### 4.5b Translocation study of environmental boundaries

A pilot translocation trial was installed in May 2005 on a ripped drill pad on Iron Hill East. In this trial, 206 *Darwinia masonii* cuttings were planted in a grid connected to a drip feed irrigation system which supplied water for an hour at a time, twice a month over the first two summers. The irrigated plants were fenced to exclude herbivores. Twenty additional plants were planted outside of the fenced and irrigated area. Ten percent (2) of these unwatered plants survive to 2010, while 89% of the watered plants survive. The surviving irrigated plants have grown rapidly to a large size and (tripling in size in their first 18 months) and have flowered extensively and precociously (with half flowering in the first year).

A second restoration trial was established in the winter of 2009. This experiment included planting nursery stock of *D. masonii* and *L. gibsonii* – established respectively from cuttings and separated clumps, together with seedlings of *Acacia cerastes* (a local species with P1 conservation status).

Plantings occurred in four sites with differing field soil substrates which included 1) deep red loam/clay plains east of Extension Hill – a material potentially available in abundance for restoration as it underlies most of the planned waste rock dump, 2) white-yellow sands of sandplains west of Extension Hill and 3) gravelly and 4) rocky loams of the north Extension Hill slope and ridge (Table 30).

Three 10m x 10m replicate plots per site were cleared and fenced before planting (Table 30). A total of 780 plants of each species were planted in July/August 2009, with 65 per plot. Monitoring of these plants started after one month and is ongoing at 3 month intervals. Monitoring has included demographic (survival, health, height, fecundity) and ecophysiological parameters (leaf gas exchange and plant water status – measured via a Li-6400 gas analyser; LI-COR Inc, Lincoln, Nebraska, USA and a Scholander-type pressure chamber; Wescor Inc., Logan, UH, USA).

**Table 30** Location of Translocation Sites on the Mt. Gibson Range.

| Site | Substrate | Replicate | Locality |
|---|---|---|---|
| 1 | BIF Rock | 1 | S29° 34' 03.9" E117° 09' 21.9" |
| 2 | BIF Rock | 2 | S29° 34' 03.1" E117° 09' 21.1" |
| 3 | BIF Rock | 3 | S29° 34' 04.1" E117° 09' 21.1" |
| 4 | BIF Gravel | 1 | S29° 34' 04.2" E117° 09' 20.5" |
| 5 | BIF Gravel | 2 | S29° 34' 03.5" E117° 09' 19.8" |
| 6 | BIF Gravel | 3 | S29° 34' 04.3" E117° 09' 19.6" |
| 7 | Sand | 1 | S29° 34' 04.8" E117° 09' 17.8" |
| 8 | Sand | 2 | S29° 34' 04.2" E117° 09' 17.3" |
| 9 | Sand | 3 | S29° 34' 04.7" E117° 09' 16.6" |
| 10 | Clay | 1 | S29° 34' 19.1" E117° 10' 29.4" |
| 11 | Clay | 2 | S29° 34' 18.3" E117° 10' 30.4" |
| 12 | Clay | 3 | S29° 34' 17.2" E117° 10' 30.3" |

By April 2010 (9 months after planting), results showed clear differences among substrates. *Acacia cerastes* established on all of the four substrates, but least successfully at the Clay site (Figure 38). *Darwinia masonii* and *L. gibsonii* demonstrated a greater specificity for substrate type with survival successful only in the BIF Rock and BIF Gravel substrate. While occasional *L. gibsonii* plants persist on the other sites they show very limited vigour and survival prospects. In terms of mean plant health and height, plants of all three species performed better growing on BIF rock and BIF gravel loams than on the clay and sandy substrates. Measurement of the physiological attributes of these plants – rates of photosynthesis, transpiration and water potential – confirm the poor performance of *D. masonii* and *L. gibsonii* on sand and clay

substrates, and indicate relatively poorer performance of *Acacia cerastes* on clay.

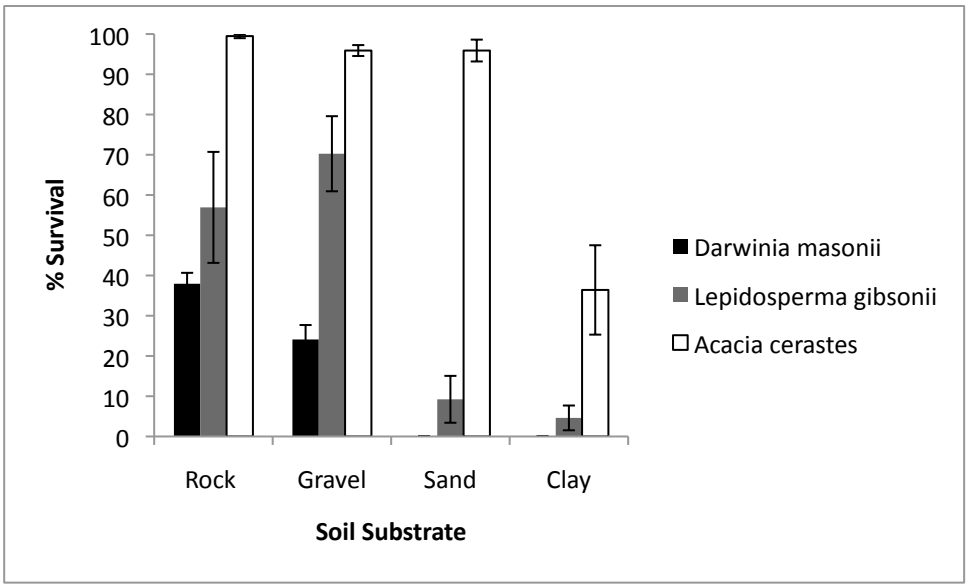



**Figure 38** Survival rates of *D. masonii* and *L. gibsonii* planted together with *Acacia cerastes* on four differing soil substrates – nine months after planting.

**Table 31**. Chemical properties of translocation substrate soils. Significance (ANOVA) indicates *p<0.05, ***p<0.001

| | units | rock | gravel | sand | clay | sig |
|---|---|---|---|---|---|---|
| EC | mS/m | 7.00 ± 2.00 | 5.67 ± 2.08 | 5.33 ± 2.08 | 2.00 ± 0.00 | * |
| pH | ($CaCl_2$) | 5.07 ± 0.15 | 4.5 ± 0.35 | 5.33 ± 0.38 | 4.33 ± 0.58 | * |
| Organic C | % | 1.91 ± 0.21 | 1.54 ± 0.32 | 0.98 ± 0.04 | 0.53 ± 0.12 | *** |
| Cu | mg/kg | 0.77 ± 0.12 | 0.53 ± 0.25 | 0.23 ± 0.06 | 1.13 ± 0.15 | *** |
| Ca | mg/kg | 610 ± 61 | 393 ± 250 | 393 ± 93 | 223 ± 170 | |
| Fe | mg/kg | 76.3 ± 8.7 | 74.0 ± 8.2 | 75.0 ± 2.6 | 27.7 ± 2.5 | *** |
| K | mg/kg | 90.7 ± 8.5 | 74.3 ± 22.0 | 43.0 ± 4.4 | 76.7 ± 46.2 | |
| Mg | mg/kg | 66.3 ± 11.1 | 41.0 ± 21.5 | 36.0 ± 16.8 | 60.0 ± 52.0 | |
| P | mL/g | 48.3 ± 12.7 | 64.3 ± 28.9 | 11.0 ± 1.0 | 66.0 ± 33.8 | |
| Mn | mg/kg | 24.7 ± 3.8 | 13.3 ± 7.2 | 16.3 ± 1.2 | 39.3 ± 25.5 | |
| Na | mg/kg | 15.7 ± 6.1 | 14.0 ± 7.5 | 14.0 ± 4.6 | 7.7 ± 4.7 | |
| S | mg/kg | 17.0 ± 3.5 | 20.3 ± 8.0 | 12.7 ± 3.2 | 10.0 ± 3.5 | |
| N total | % | 0.10 ± 0.01 | 0.07 ± 0.02 | 0.05 ± 0.00 | 0.04 ± 0.01 | *** |
| B | mg/kg | 1.00 ± 0.44 | 0.80 ± 0.52 | 0.57 ± 0.12 | 0.40 ± 0.17 | |
| Co | mg/kg | 0.08 ± 0.02 | 0.04 ± 0.01 | 0.08 ± 0.02 | 0.56 ± 0.35 | * |
| Ni | mg/kg | 0.17 ± 0.06 | 0.13 ± 0.12 | 0.17 ± 0.06 | 0.30 ± 0.10 | |
| P | mg/kg | 5.67 ± 2.08 | 3.67 ± 1.53 | 4.00 ± 0.00 | 5.33 ± 0.58 | |
| Zn | mg/kg | 1.00 ± 0.36 | 0.67 ± 0.23 | 0.5 ± 0.17 | 0.83 ± 0.23 | |
| Pb | mg/kg | 1.00 ± 0.00 | 0.87 ± 0.15 | 0.43 ± 0.06 | 0.87 ± 0.12 | *** |

The properties of translocation site soils were assessed via chemical analysis (WA Chem Centre, one bulked sample of 5 subsamples of 0-10cm depth per plot) and soil moisture probes. Three moisture probes were installed in one plot of each substrate type: these were set to record every 10 minutes (Hobo microstation S-SMC-M003 ECH2O soil moisture probes: Onset Computer

Company). Soil chemistry differed several respects between sites, most significantly in C content, Fe, Cu, Pb and total N. Electrical conductivity, pH and Co also varied significantly (Table 31). pH was highest at the Sand site and lowest at Clay – although all were acid, and EC was much lower at the Clay site than any other (associated with lower Na and Ca). Organic C content and % total N were highest at the Gravel and Rocky loam sites. Fe was lowest, and Cu and Co highest at the Clay site. Of these differences, N is likely the most important for plant growth and survival.

Higher % organic C in Gravel and Rock site soils may be indicative of a simple, but significant, role of gravel and rock in these substrates. By excluding water and other inputs., the presence of gravel and rocks in soil means that identical rainfall inputs over a unit area of surface is concentrated into a smaller volume of soil so that in a uniform rainfall event, rocky soils receive and hold a greater volume of water than non-rocky soils. The same process occurs with other soil inputs sourced from above-ground, such as organic C.

In seasonal and low rainfall regions, soil water availability is usually more limiting to plant growth than soil nutrition. Soil probe outputs show that while soils attain similar maximum and minimum soil moisture concentrations, the Sand, and Clay site soils appear to dry out more rapidly than those at the Rock and Gravel sites (Figure 39). Clay site soils appear to wet more quickly, or more responsively to smaller rain events, but the Gravel and Rock site soils also reached slightly higher maximum water contents than the other sites (27-28% v 24-25%). Soils of different composition and texture bind water with different potentials, so that water in soils of differing texture but similar water content may, from a plant's point of view, differ in the availability of water and the ease with which it can be extracted. Also important for plant survival is the period for which plants experience water availability levels above or below key thresholds (e.g. wilting point). While observed soil dry-down rates may not appear to differ markedly, the slightly slower drying curves of the Gravel and Rock sites may lead to plants experiencing significantly longer periods of favourable water availability in these sites.

The pattern of soil moisture with depth in the soil profile is also unknown and may differ between sites. Rock and gravel cover effectively reduce the area of exposed soil surface and thereby act to limit surface evaporative losses on a volume basis.

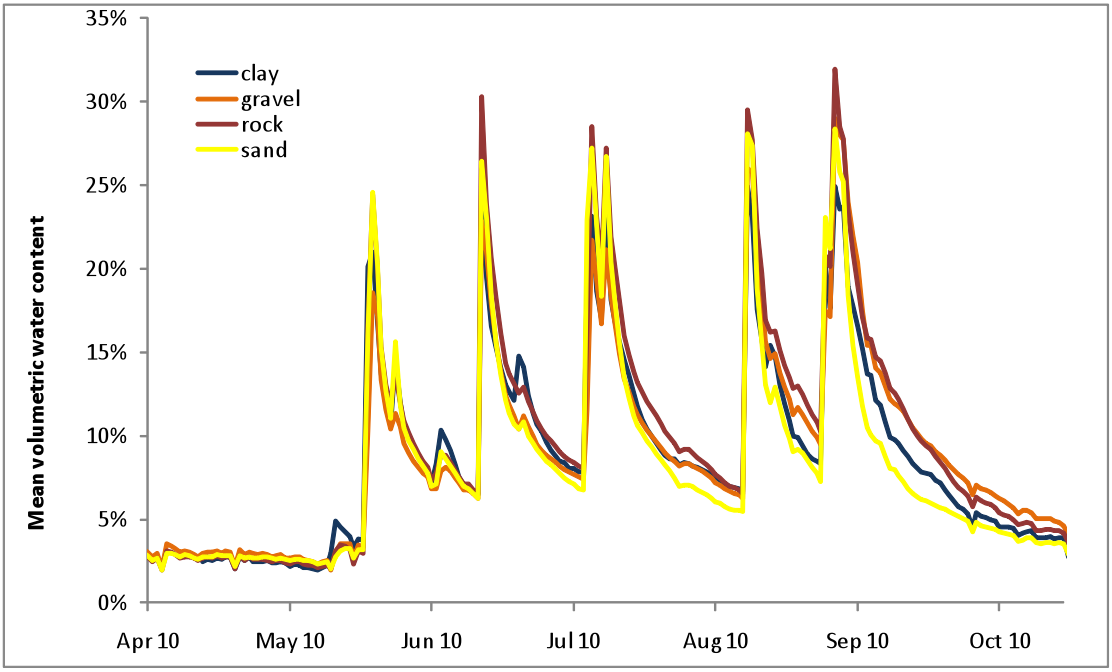



**Figure 39** Mean daily maximum soil moisture content at 5cm depth for translocation trial sites on differing substrates (average of three Hobo microstation S-SMC-M003 ECH2O soil moisture probes, Onset Computer Company). Winter 2010

## Summary

- Both *D. masonii* and *L. gibsonii* have the ability to be planted and survive in restoration sites
- Survival and establishment of translocated *D. masonii* and *L. gibsonii* individuals was effectively limited to BIF rock and BIF gravel sites
- Survival to 9 months of transplanted *D. masonii* greenstock averaged under 40% at its best performing site (BIF rock)
- Transplanted *L. gibsonii* survival (to 9 months) was greatest on BIF gravel sites (~70%) but was also high (>50%) on BIF rock sites
- Translocation sites differed in several soil properties, of which patterns of moisture content and total Nitrogen may be the most critical.

## Recommendations

- Sand and clay substrates may not be effective restoration materials for *D. masonii* and *L. gibsonii*, although mixing clays with quantities of rock and/or gravel may be worth trialling.

- Final restored structure surface should incorporate a large proportion of BIF rock or gravel for successful restoration of both *Darwinia masonii* and *Lepidosperma gibsonii*.

- Field studies in which *D. masonii* and *L. gibsonii* are translocated into restoration substrates designed with varying amounts of rock and gravels, and with rocks at varying depths are recommended to ensure optimal restoration success.

### 4.5c Drought study

Many of the studies in this and the next section are comparative, with the target species studied in comparison with a range of other taxa. Comparator species included 2-4 of the most closely related taxa (*Darwinia acerosa*, *D. purpurea*, *Lepidosperma* sp. 'costale' Wanara, *L.* sp. 'costale' Beanthiny, *L.* sp. Wubin biconvex, *L.* sp Wubin scabrid) as well as species which are less closely related but co-occur with *D. masonii* and *L. gibsonii* at Mt Gibson but are also common / widespread across a range of habitat types – *Gahnia drummondii* (Cyperaceae) and *Amphipogon caricinus* var. *caricinus* (Poaceae) and *Aluta aspera* subsp. *aspera* (Myrtaceae). The purpose of comparisons with related species is to identify if observed traits are adaptations specific to the target species or shared among close relatives, and therefore pre-dating the evolution of the modern species and excluding specific adaptation to their modern habitats. Comparisons with widespread species indicate the extent to which observed traits are shared with other species in the same habitat.

Drought studies were performed under controlled glasshouse conditions and involved comparisons with several closely related *Lepidosperma* and *Darwinia* taxa. These experiments took two forms, one investigating root growth and biomass accumulation under drought conditions and the other measuring physiological response to declining water availability.

In the root growth and biomass accumulation study 80 individuals from each species were transplanted into free draining custom-made PVC tubes (1 m deep and 0.1 m diameter). Soils were white sands with addition of 59 mL of diluted nutrient solution (200μM Ca $(NO_3)_2$, 100 μM $K_2SO_4$, 4 μM $KH_2PO_4$, 54 μM $MgSO_4$, 0.24 μM $MnSO_4$, 0.10 μM $ZnSO_4$, 0.018 μM $CuSO_4$, 2.4 μM $H_3BO_3$, 0.030 μM $Na_2MoO_4$, 40 μM Fe-EDTA – following Poot and Lambers 2008). Tubes were held upright in a metal frame and watered twice daily from overhead sprinklers during an establishment period (2 months) prior to drought treatment. Plants were subsequently exposed to drought (no

watering) and control (250 mL of water twice a week) treatments over a period of four months.

After 72 days, droughted plants had significantly higher root growth and lower stem growth (ANOVA $p<0.05$) than non-droughted plants in both species (Figure 40). Examination of the distribution of dry mass down the profile in the tube-pots showed that this extra root growth occurred at all depths.

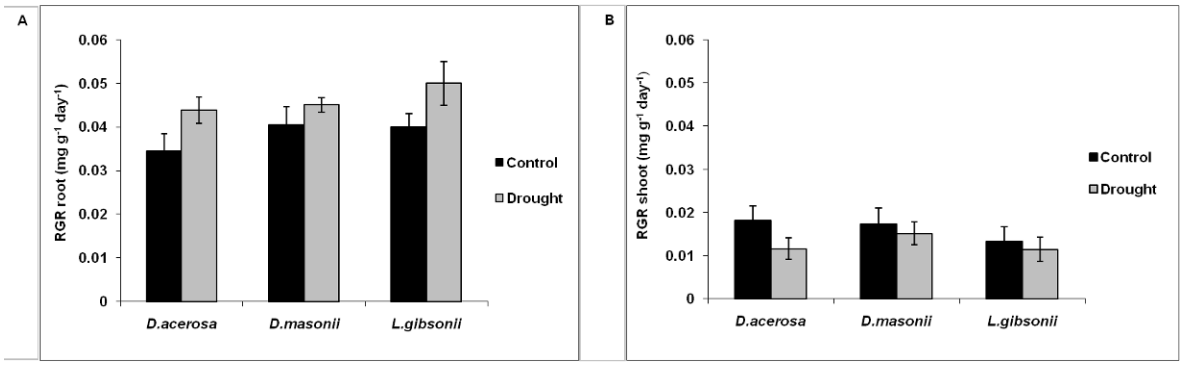



**Figure 40.** Relative growth rates (RGR) of shoot dry mass (A) and root dry mass (B) over a 72 day period. Comparison of control (black bars) and drought plants (grey bars) *Darwinia acerosa, D. masonii* and *Lepidosperma gibsonii* respectively. Bars represent means ± SE (n=8 per harvest).

In this experiment, *D. masonii* plants had greater total leaf surface area than did *L. gibsonii* (likely simply a result of plant selection), but *L. gibsonii* had a significantly larger difference in total leaf area between control and droughted plants (drought plants had 50% of the area of watered plants) than did *D. masonii* (10% difference).

Treated plants in this study were also examined for their plant water status and photosynthetic activity. Water status was assessed via measurement of both pre-dawn and midday xylem pressure potential using a Scholander-type pressure chamber (Wescor Inc., Logan, UH, USA). Midday plant water potential reflects both the level of soil water potential and the transpiration activity of the plant during the day. The absence of photosynthetic activity during the night means that pre-dawn plant water potential are generally in equilibrium with the soil water potential. Photosynthesis, C-assimilation and transpiration rates were measured for each plant in the study using a portable infrared gas analyser (Li-6400, LI-COR Inc, Lincoln, Nebraska, USA).

The difference between midday and pre-dawn water potential of drought plants was greater for drought plants than controls in *L. gibsonii* but less so for *D. masonii.* There was little difference between species in their rates of

photosynthesis and transpiration, although *L. gibsonii* did have slightly lower rates than *D. masonii* at 72 days.

In a second study, 15 plants of each of *D. masonii* and *L. gibsonii* were grown, together with closely relative taxa *D. purpurea*, *D. acerosa*, *L*. sp Wubin bi-convex and *L*. sp Wubin scabrid, in free draining 25 cm diameter × 40 cm deep pots. This study was designed in order to control soil moisture conditions as closely as possible and to ensure that samples of each species were exposed to identical soil moisture conditions. Pots were lined with a fine nylon fabric prevent soil loss and filled with a known weight of oven dried, commercial loamy sand. All materials were weighed in initial dry conditions and then watered to field capacity. Pots were subsequently weighed at intervals to determine soil gravimetric water content. Pots were then watered in controlled volumes to maintain or manipulate water content at desired levels for testing over a period of 85 days. Plant physiology was measured using the Li-6400 as described above and plant drought response curves based on soil water potential were assembled for each species. The relationship between gravimetric water content and soil water potential was established for the experimental soil using an inverse van Genuchten Equation (van Genuchten 1980). This equation was constructed from measurements of the two parameters made using the pressure plate method (Wild 1988) (n = 3) at -0.01, -0.10, -0.3, -1 and -1.5 MPa as well as using the vacuum desiccator method (Bulut 1996) at -39, -98, and -316 MPa.

Water potential is expressed in units of pressure required to remove water from the target material. Its units are negative as the process requires a vacuum to extract water. Values of water potential close to 0 indicate water can be extracted with little effort, while larger negative values indicate dryer conditions.

Plants were exposed to soil water potentials between -0.00052 to -1.3 MPa. Establishing the point at which plant function ceased is a delicate matter as a small change in soil water content corresponded to a large change in soil water potential in very dry soils so that the critical soil water potential when the gas exchange of the plants ceased occurred over a narrow range (a few hours to a few days). Results identify the lowest soil water potential under which plants were measured to be functioning and the next lowest measurement when they were not. *Lepidosperma* sp Wubin scabrid appeared to cease gas exchange at a higher water potential (between -0.6 and -0.7 MPa) than the other *Lepidosperma* species (-1.0 and -1.1 MPa for both *L. gibsonii* and *L*. sp Wubin bi-convex). Differences between the *Darwinia* species were less clear

(all between -0.8 and -1.3 MPa) but encompass the range of the *Lepidosperma* species (Figure 41).

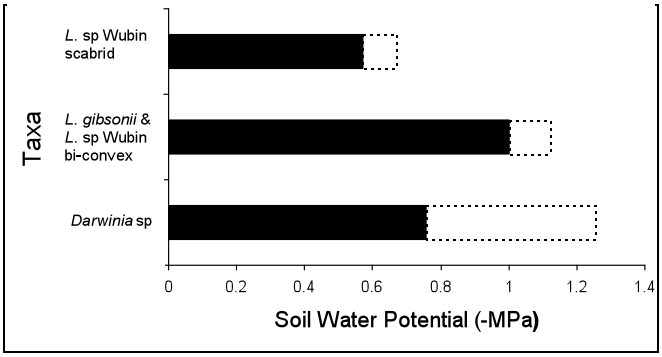



**Figure 41** The soil water potential at which measured photosynthesis rate (A) became zero or negative. Black bars are based on last time of measurement when A was still positive, dotted ranges are based on the next time of measurement when A was zero or negative.

Drought response curves differed between genera as *Lepidosperma* species had lower rates of photosynthesis at maximum water potentials than the *Darwinia* species did. *Darwinia masonii* recorded among the highest rates of photosynthetic activity in the study, and *Lepidosperma gibsonii* recorded the lowest even when well watered (Figure 42).

Water use efficiency (WUE) was calculated for examined plants – on the basis of ratio of Carbon assimilated per water lost – across the range of soil water potentials (Figure 43). *Darwinia* species were able to maintain their WUE with declining water availability, while *Lepidosperma* species were able to increase their efficiency. Both *D. masonii* and *L. gibsonii* had relatively low and broadly similar WUE. *Darwinia acerosa*, a DRF species from granite areas closer to Perth, had significantly higher WUE than other *Darwinia* (and *Lepidosperma*) species ($t_{78}$ = 3.64, P <0.001). This habitat of this species has higher mean rainfall than that of any other tested.

It is important to note that the soil water potentials that were able to be imposed in these experiments – and which were ultimately lethal at their lowest levels – were all considerably wetter than the levels that are frequently recorded in the field (e.g. Figure 44). This illustrates the difficulty of transferring glasshouse experimental results to field conditions, but also identifies the key strategy employed by most of the experimental species, including *D. masonii* and *L. gibsonii*, which is to avoid drought. Drought avoidance, as opposed to drought tolerance is a strategy whereby, plants do not function under drought conditions, but instead cease photosynthetic function and try to conserve water and survive through to a time when soils

become moist again. The implication of this strategy is that plant tissues must have the capacity to desiccate to a very high degree, remain alive under such conditions and then regain metabolic function when soils rewet.

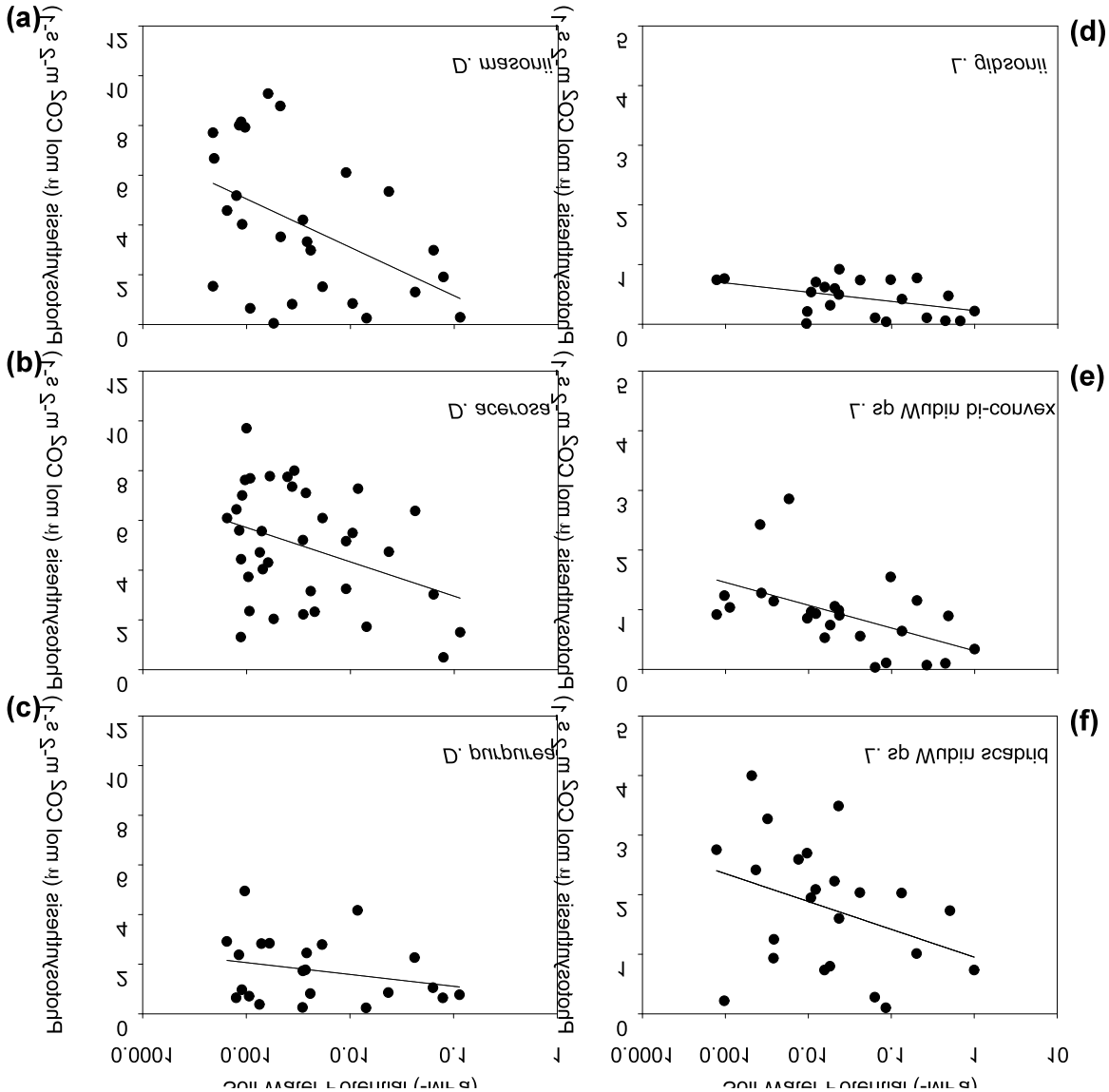



**Figure 42.** The response of photosynthesis to varying soil water potential for the target species (a) & (d) and their respective congeners. Points are multiple measurements of individual plants taken at various points through time. Note different Y-axes for each genus and log X-axis scale. Linear regressions fitted to the log transformed soil water potential data are significant for *Darwinia masonii*, *D. acerosa*, *Lepidosperma gibsonii* and *L*. sp Wubin bi-convex ($p<0.05$)

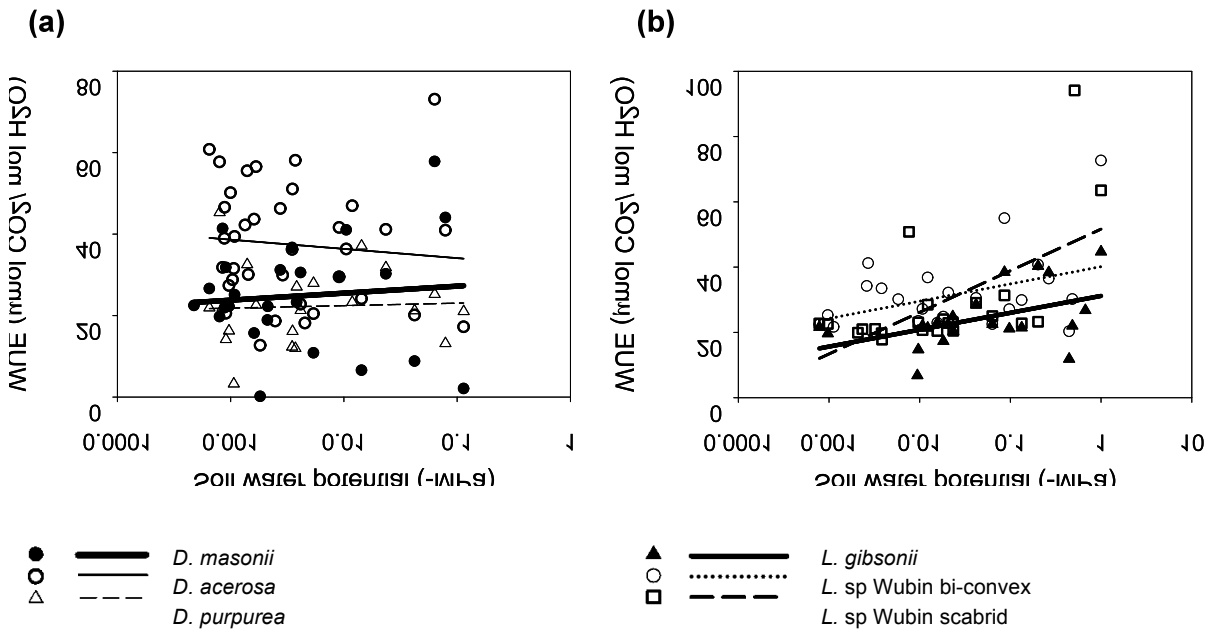



**Figure 43.** Intrinsic water use efficiency (WUE) of (a) the *Darwinia* species and (b) the *Lepidosperma* species with varying soil water potential. Intrinsic water use efficiency is photosynthesis/ stomatal conductance.

Both species have relatively low water use efficiency when they are functioning, and respond to lower soil mater availability by increasing root growth at the expense of reduced shoot growth. *Lepidosperma gibsonii* has low maximum photosynthetic rates, lower WUE, a greater root growth response to dryer conditions. *Darwinia masonii* on the other hand has high maximum rates of photosynthesis

**Summary:**

- Comparative studies of *D. masonii* and *L. gibsonii* and related species of other environments demonstrate that the target taxa do not possess unique capacity to function or use water at lower levels of water availability.
- Both species do respond to declining soil moisture levels by increasing root growth at the expense of investment in leaves and shoots.
- *D. masonii* and *L. gibsonii* appear to persist over the arid summer period by closing down plant function and maintaining a dormant state through to next winter.

### 4.5d Plant response to environmental variation

The environment experienced by *D. masonii* and *L. gibsonii* has been investigated via assessment of site factors, soil and surface properties and modelling of distributions in respect of environmental variables (**4.5a Abiotic associations**). The role of fire in the mortality and recruitment of plants has been examined in section 4.2 Population Demography, and the role of climatic variation – as much as was possible within the study period (section **4.2** and **4.3b Seed production**). The response of *D. masonii* and *L. gibsonii* to experimentally induced drought conditions is described in section **4.5c** above. This section presents addition studies of the physiological behaviour of *D. masonii* and *L. gibsonii* under field conditions.

Seasonal monitoring of plant ecophysiology has been ongoing at Mt. Gibson since 2008. This survey (of 145 plants of 5 species) characterises ecophysiological strategies in terms of seasonal variation in leaf gas exchange and plant water status, comparing *D. masonii*, *L. gibsonii* and *A. cerastes* with common/widespread relatives (*Aluta aspera* subsp. *aspera* and *Amphipogon caricinus* var. *caricinus*. 8-11 plants are monitored every three months at each site.

**Table 32.** Location of sites used in ecophysiological monitoring.

| Site | Species | Location | Age Class | Locality | n |
|---|---|---|---|---|---|
| 1 | *D. m.* | Mt Gibson | Adult | S29 35 37.4 E117 11 03.7 | 11 |
| 2 | *D. m.* | Iron Hill | Seedling | S29 36 25.4 E117 10 46.4 | 8 |
| 3 | *D. m.* | Mt Gibson South | Adult | S29 36 12.9 E117 12 00.6 | 11 |
| 4 | *D. m.* | Extension Hill South | Adult | S29 35 04.4 E117 10 00.7 | 11 |
| 5 | *L. g.* | Iron Hill | Adult | S29 36 16.8 E117 10 23.4 | 11 |
| 6 | *L. g.* | Iron Hill North | Adult | S29 35 59.3 E117 10 14.6 | 10 |
| 7 | *L. g.* | Extension Hill South | Adult | S29 35 04.9 E117 10 00.0 | 11 |
| 8 | *L. g.* | Mt Gibson | Adult | S29 35 39.1 E117 11 03.7 | 11 |
| 9 | *L. g.* | Mt Gibson | Seedling | S29 35 39.1 E117 11 03.6 | 11 |

Ecophysiological monitoring indicates that there are no differences in mean water potential or leaf gas exchange attributes (photosynthesis and stomatal conductance) between *D. masonii* and *L. gibsonii* and non BIF-endemic species from all sites (e.g. Figure 44 – gas exchange parameters, and other sites show similar patterns). All species examined show the same diurnal and seasonal patterns, with both gas exchange and water potential parameters indicating active growth and C-uptake during winter, but an almost complete cessation of growth over summer and autumn. These results do not support the theory that *D. masonii* and *L. gibsonii* have root foraging (or other)

strategies which enable their access to water that other species are not – but which may cause them to be limited to the BIF substrate. They are, however, very drought tolerant through the simple drought avoidance strategy of shutting down function completely over summer and autumn. The process of this shut down is illustrated in Figure 45 and Figure 46.

These physiological measurements (e.g. Figure 44) additionally illustrate the effect of winter drought, with pre-dawn water potentials in winter of 2010 much higher than the levels measured exactly 12 months previously, and approaching those observed in the summer of 2008/09.

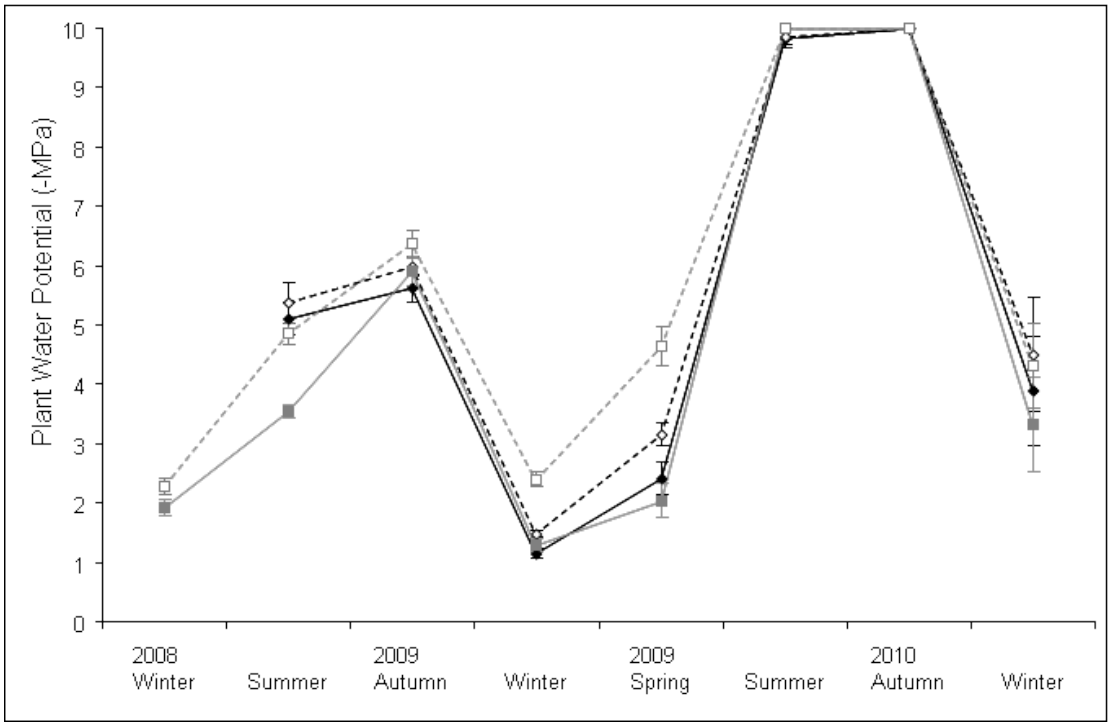



**Figure 44.** Mean (± SE) Water potential of Mt Gibson *Darwinia masonii* (grey) and Iron Hill *Lepidosperma gibsonii* (black) populations from mid 2008 to mid 2010. Water potential readings observed pre-dawn (dashed: 0400-0600hrs) and PM (solid: 1200-1400hrs).

### 4.5e Plant health

Plant health scores have been discussed previously under **Population demography** (**4.2**), interactions with predators and parasites are described under **Biotic Interactions** (**4.5g**, below) and plant physiological behaviour is discussed above (**4.5c, 4.5d**).

**Figure 45.** *Darwinia masonii* foliage passing through seasonal changes. Leaves and stem are produced in autumn and winter and function through to spring. They enter a dormant state over summer, and regain their green colour and photosynthetic function with the onset of rains. Most leaves survive through one or two summers and function through two or three winters. Left (July): Previous season's leaves re-greened and new season growth commenced. Centre left (December): last season's growth lost, showing much bare stem. Centre right (January) and Right (April): last season's growth yellow-grey in drought mode.

**Figure 46.** *Lepidosperma gibsonii* **l**eaf growth commences with onset of rains and continues through winter (left). Growth ceases in late spring and leaves change colour through December (centre left) and January (right).

A quantitative health score based on comparing foliage colour with colour tables was trialled for both species, with the aims of reducing the subjectivity of scoring, and of deriving further information on plant vigour. However, foliar colour is observed to change seasonally in both species, with even the healthiest plants attaining a colour in early autumn comparable with that of the least healthy plants in early spring. This coloration is likely an adaptive mechanism which protects leaf photo-systems from damage due to excess light and heat during the period when they are unable to repair themselves, or make use of available light, due to the lack of water. Photosynthesis ceases

as soils dry during over summer and leaves remain yellow or orange through until rains return, whereupon leaves re-green and start photosynthesis and growth again. Leaves of both species appear capable of surviving through one or two summers, although, in more sheltered positions they may survive longer. Leaves therefore function through 2-3 winters. Any quantitative colour score would need to be finely calibrated for season and soil moisture content.

### 4.5f Below ground adaptations

The root growth and foraging abilities of both species were examined in experimental studies investigating root vertical and horizontal growth capacities, and in their ability to penetrate small pore spaces and fissures. Excavation of the root systems of *D. masonii* seedlings and *L. gibsonii* clumps was also undertaken in the field. The response of root mass growth of both species to experimentally imposed drought has been described previously (section 4.5c).

Vertical root growth was relatively rapid in glasshouse experiments. Root extension was determined by comparing root depths among plants of each species grown from cuttings (*D. masonii*) and clump separation (*L. gibsonii*) in white sand in 1 m deep and 0.1 m diameter PVC tubes (as detailed in 4.5c) when harvested at 28 days versus 72 days after planting. Eight individuals of each species were harvested at each period. Over this 44 day period, roots of well watered plants of both species when harvested at 72 days, were on average 24 and 25 cm deeper than those of plants harvested at 28 days. These measurements suggest a rate of vertical growth of 5.5 and 5.7 $mm.day^{-1}$ for *D. masonii* and *L. gibsonii* respectively. Under drought conditions, *D. masonii* root growth was similar (6.1 mm.day-1) but *L. gibsonii* root extension declined (to 3.0 $mm.day^{-1}$). As the experimental plants of *L. gibsonii* were initially larger than those of *Darwinia masonii*, and plant growth often increases with size, it may be more appropriate to compare the ratio of root growth rate relative to initial size (relative growth rate), which would then be 0.4 and 0.9 over this 44 day period. By the end of the study program, the root systems of many individuals of both species had reached the bottom of the 1 m pots.

A second glasshouse study examined rates of horizontal root extension by growing cuttings transplanted into custom made containers (1.8 m long, 0.2 m wide and 0.15 m deep) filled with course white sand to a depth of 0.1 m. These long pots had transparent polycarbonate bases covered externally with black plastic to maintain humidity and shield roots from light. Plants were flushed once a fortnight with approximately 500 ml of the standard nutrient solution and grown in well-watered conditions. Root growth was periodically

examined by observing the transparent base of each pot, and all pots were harvested and root distributions assessed after five months when the first roots were observed to have reached the end of the 1.8 m long pots. In this study five individuals of each of six species (*D. masonii* and *L. gibsonii* and two closely related taxa) were compared. In this study horizontal root growth was measured at around 1.5 mm.day-1 for *D. masonii*, slower than its close relative, the sandplain species *D. purpurea*, but similar to another shallow soil endemic species (*D. acerosa*, which occurs on granites). *Lepidosperma gibsonii* horizontal root extension rates averaged 3.5 mm.day$^{-1}$.

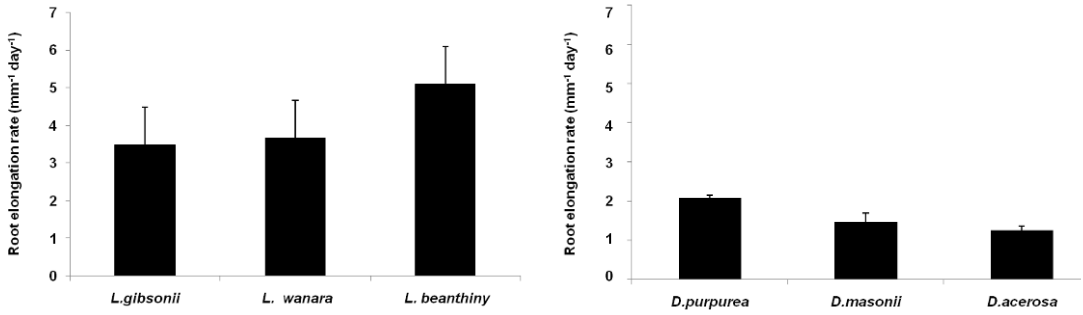



**Figure 47.** Horizontal root extension over the bottom of 1.8 m-long containers over a period of 44 days of three *Darwinia*, and three *Lepidosperma* taxa, once the roots reached the bottom. Error bars indicate standard errors (n=5)

A final study examined the capacity of roots of target species, and of two near relatives per genus, to explore soil areas by entering into small apertures such as pores and cracks in rocks. This study utilised plants grown in climate controlled glasshouse in 550mm x 90mm diameter PVC tubes with soils and nutrient additions (as above) and watered daily. Five replicate control plants of each species were grown in 55cm tubes without any restrictions, and another five replicates were grown in a sealed stack of six 5cm high sections, each of which had a sheet of stainless steel woven wire mesh (Metalmesh) siliconed to its base. A 15 cm top segment with a mesh bottom was attached upon the top of the stack to accommodate the planting of seedlings. Mesh sizes were based on the measured diameters of roots for each species and ranged from 34 to 530 µm. Plants were harvested when roots from control plants were observed to have reached the bottom of their pots (at 5 months). Sections were carefully separated on harvesting with root dry mass and root length measured and the number of root mesh penetrations counted. Controls were also cut into sections corresponding to the sections of the treatments, in order to provide comparison with an unobstructed root profile. Each section of roots (both treatments and controls) was scanned at high resolution, using the WinRhizo Pro 2007d software package (Regent Instruments, Quebec, Canada) and an Epson Perfection 4990 photo scanner.

Sections of fine roots taken from free growing plants were also examined under a microscope to identify elements of their anatomic structure (Figure 48). Of key significance is the diameter of the root itself, and of the root stele. Previous work (Zwieniecki and Newton 1995) had identified the root stele diameter as the major factor limiting pore entry of roots of shallow soil species. The stele occupies the centre of the root section and consists of the bundled vascular cells which transport water, nutrients and sugars around the plant. Stele diameters did not vary within genera but larger among *Lepidosperma* species (averaging 223 µm, relative to the average of 102 µm for *Darwinia* species). Root diameters were more variable, averaging 3-5 times that of the stele.

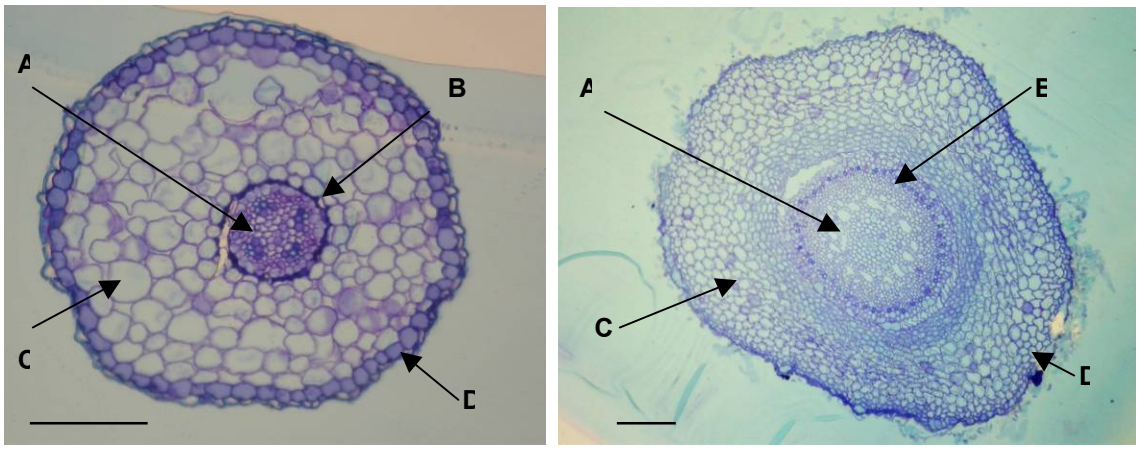



**Figure 48.** Root sections of *Darwinia masonii* (left) and *Lepidosperma gibsonii* (right). Root samples were imbedded in resin using biowave technology, sectioned, and stained with toluidine blue. Letters indicate the root stele (a), endodermis (b), cortex (c) and epidermis (d). Bars represent 100 µm.

Examination of number of root penetrations, root mass and total root length below mesh barriers identified differences between species within genera, as well as between genera. *Darwinia* root penetration was severely limited at the 100 µm mesh barrier and effectively prevented at a 63 µm mesh. Root penetration by *Lepidosperma* species was reduced at the 260 µm mesh, and no *Lepidosperma* species penetrated the 150 µm mesh.

Root excavations were performed in the field using brushes and a compressed air jet. Two *D. masonii* seedlings and one *L. gibsonii* clump were excavated from within the mining footprint on Extension Hill. In both cases, root systems were successfully traced up to the point when roots passed into, or beneath larger, immovable rocks. Unfortunately, in each case this occurred within 10-15 cm and roots passed into rock and regolith which could not be excavated with the tools available.

In the case of *D. Masonii*, plants were 5 months old and 5-6cm tall. They were each found to be emerging from seeds (still attached) buried at 3-4 depth, and with root systems traced a further 6 cm, to a total depth of ~10 cm (Figure 49). In the case of *L. gibsonii*, the excavated plant was a small sized mature individual likely dating from the 1969 fire. It had a well developed root system, with ~30-40 individual roots emerging from the clump base. These spread diagonally downwards, but could be traced for only 10-15cm before entering crack and pore spaces in rock-like regolith material (Figure 50).

**Figure 49.** Excavated *Darwinia masonii* seedling from within the mining footprint on Extension Hill; October 2009, following May 2009 experimental fire. Seedling height 5 cm, seed depth 3 cm, roots excavated to 10 cm depth – and continuing into rock cracks. Arrows show seed attached to stem (below) and ground level (above).

**Figure 50.** Site from which the root system of a *Lepidosperma gibsonii* plant was excavated from within the mining footprint on Extension Hill. The roots of the excavated plant (basal diameter 80 mm) extended to 15 cm depth before terminating at, or entering hard regolith surfaces (several indicated with arrows).

Examination of seven mining drill cores from Extension Hill, including from localities close to individuals of *D. masonii* and *L. gibsonii* revealed extensive weathering of underlying regolith with abundant solution channels, large cracks and pores. Many of these cracks, including to depths below the surface much exceeding the height of the vegetation above ground, contained visible root material (Figure 51). While one core (with sand overlaying weathered rock) had no visible roots, and one had roots only to 1.1m others had roots extending to over to 10 m, one to 13 m (Figure 52). While it was not possible to identify the plant species, and there are a number of candidate species, it is feasible that either study species could possess root systems with the capacity to exploit weathered regolith to this depth.

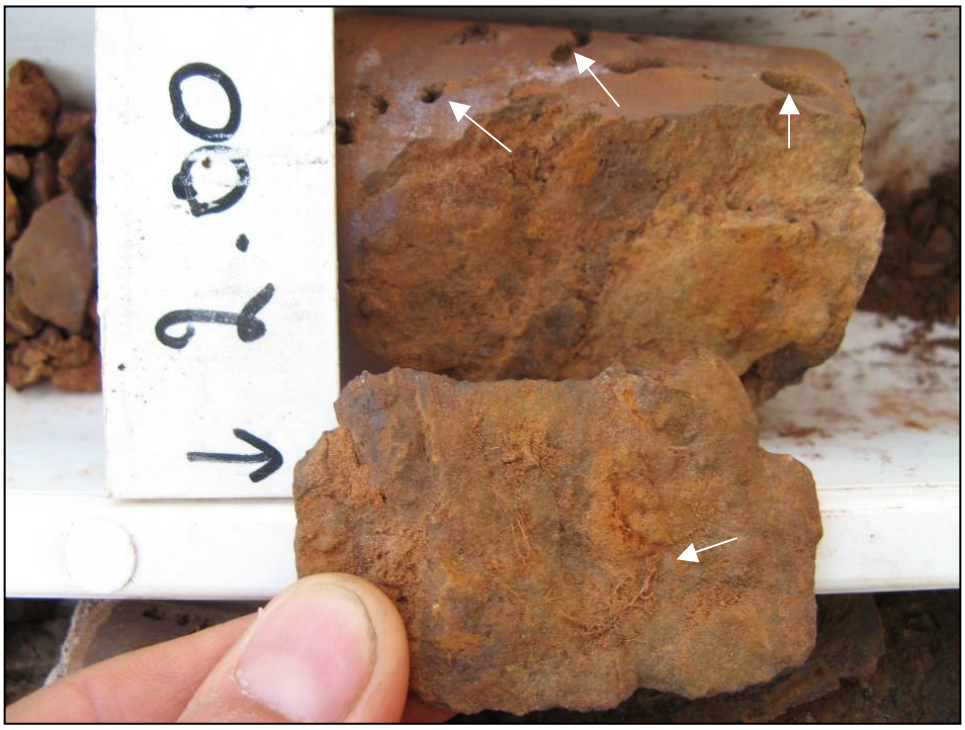



**Figure 51.** Example of roots (lower white arrow) observed in a natural break in a rock core form Extension Hill, here at 2 m depth. Note also solution channels in rock above (upper white arrows)

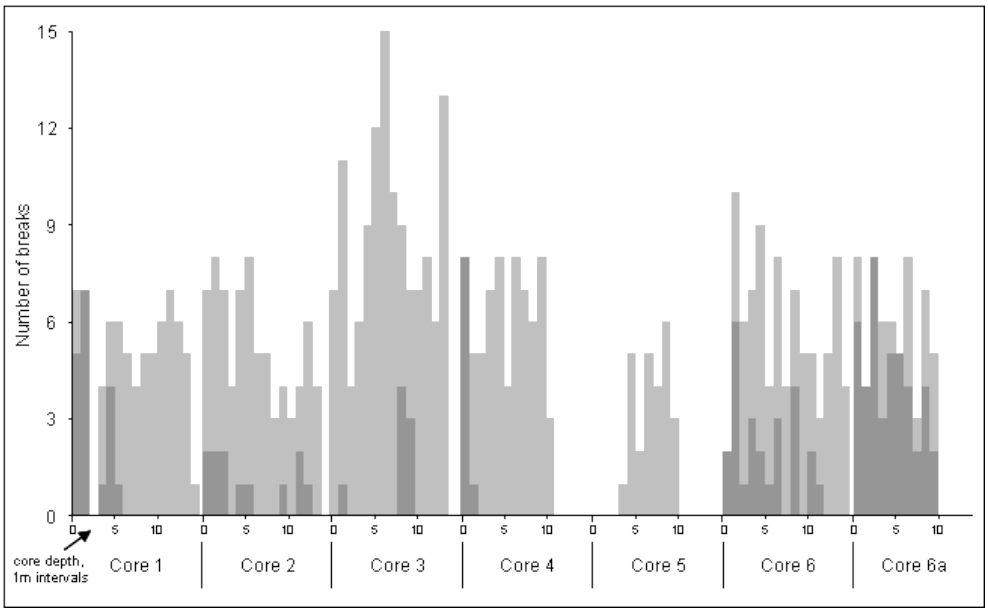



**Figure 52.** Frequency of root observations (dark grey) among breaks (fissures and cracks, light grey) in 1m sections of seven 50mm drill cores from Extension Hill.

Planned excavations of whole root systems with the aid of mining technology were not undertaken as mining development had not reached this stage during the period of the study.

**Summary**

- Results of these research programs show a capacity of both *D. masonii* and *L. gibsonii* for rapid horizontal and vertical root growth under good conditions and root growth is relatively increased in drying soils.

- Measured rates of root growth were faster for both species in vertical orientations than horizontally. Both species had similar rates of vertical growth (5-6 $mm.day^{-1}$), but *L. gibsonii* grew faster horizontally (3.5 v 1.5 $mm.day^{-1}$).

- Roots of both species grew to 1m depth and a similar horizontal extent over a period of a few months in glasshouse conditions.

- *Lepidosperma gibsonii* roots are generally larger than those of *D. masonii*, and are more restricted in the size of soil and root spaces that they can enter.

- Neither BIF species showed root growth adaptations that were significantly different from close relatives from non-BIF habitats.

- Excavations indicate a capacity of roots to enter large cracks, pores and fissures in regolith, and examination of drill cores show that the regolith is highly porous and that some plant species do achieve root depths exceeding 10m in the BIF system.

**Recommendations**

- Proposed examination of root systems in mine pit faces should proceed as mining commences through populations of *D. masonii* and *L. gibsonii*, but are likely to prove challenging as roots pass through solution channels and fissures in rock. These studies may help to determine rooting depth of *D. masonii* and *L. gibsonii* and their use of surficial versus deeper layers in the soil profile. Results would inform requirements for restoration substrates.

- Mapping of regolith may indicate a relationship with the distribution of *Darwinia masonii* around the range which may reveal an important but as yet unknown association of the species with particular fracture patterns or density.

### 4.5g Biotic interactions

***Darwinia masonii***

**Vertebrate grazing** impacts have been considered a possible threat for *Darwinia masonii* populations. However, mortality among seedlings protected from herbivory by a coarse (chicken wire) steel mesh was similar to that observed among uncaged seedlings (see **mortality/survival** under **4.2 Population Demography** above). Further, no evidence of mammalian herbivory was observed on any plant, seedling or adult in the demographic survey plots or outside of these (with the exception of a single cutting damaged by a presumed rabbit-bite, but not actually grazed, and therefore likely to be an isolated instance ), and it is not considered to be a current threat. Four tagged flowering plants were observed to have had branch tips cut off (2007 only). Further evidence of this impact was observed elsewhere in 2007, and was presumed to result from the actions of parrots eating developing seeds or flowers.

**Invertebrate herbivory.** Galls were observed on a very small number of *Darwinia masonii* individuals (Figure 53), but other evidence for foliar loss or damage from insect attack was not noted.

**Figure 53.** *Darwinia gibsonii* leaf gall.

**Termites** were observed on stems of 15 of 357 tagged *Darwinia masonii* individuals. One of these individuals was from a site last burnt in 1969, the remaining 14 were from older sites: respectively this represents 0.7% and 15% of individuals in these site ages. Termites were observed with their trails ascending the stems of *D. masonii* plants, and in one case had hollowed out a dead stem, their impact never appeared significant, and the mean of growth rates and health scores of affected individuals did not vary greatly from the mean of termite-free individuals in the same areas.

**Pollination** experiments describing the role of birds (white cheeked honeyeaters) and insects in pollen transfer are described under section 4.3e. Extensive s**eed predation** by moth larvae and **seed dispersal** by various ant species are described under sections 4.3b and 4.3f respectively.

**Mycorrhizal associations:** Examined field-collected root-systems of *D. masonii* clearly showed Vesicular-Arbuscular mycorrhizal (VAM) colonisation, but no obvious Ectomycorrhizal (ECM) formation. VAM associations are ubiquitous in Myrtaceae, and ECM associations common in Myrtaceae. Few shrubby Myrtaceae have been investigated for ECM associations, but an ECM partnership between *Chamelaucium uncinatum* (a sister-genus of Darwinia) and *Pisolithus* sp. has been documented at Kalbarri. No evidence of fruiting of ECM fungi was observed in the vicinity of *Darwinia masonii* plants during this project; however, some ECM-forming fungi were observed fruiting elsewhere in the range (*Amanita* spp., *Torrendia inculta*, *Pisolithus* sp., *Entoloma* sp., which were probably associated with *Eucalyptus* and/or *Acacia* spp.). Mycorrhizal formation is potentially important for restoration success for *D. masonii* (e.g. for seeding survival and growth rate, as has been shown for a variety of VAM and ECM-forming species), and should be further investigated in comparative restoration trials, in particular whether restoration-planted seedling are spontaneously able to form mycorrhizal associations in restoration surfaces, or whether inoculation is required or beneficial.

**Fungal infections:** Only a single unidentified bracket fungus has been observed fruiting on *D. masonii* trunks during this study. Wood of dead or burnt *D. masonii* plants persists for many years after death, with no obvious indication of fungal rotting. In contrast, living *Melaleuca nematophylla* was frequently observed colonised by *Fulvifomes* sp., and numerous plant species had dead wood colonised by *Pycnoporus coccineus* and numerous corticioid wood-rotting species. It is likely that wood rots have a very minor impact on *D. masonii*.

Evidence for **competition or facilitation** (i.e. negative or positive interactions with neighbouring plants) was also not observed, however such interactions are best determined by manipulative experiments under field conditions. Such experiments are suggested for future restoration research.

***Lepidosperma gibsonii***

**Vertebrate grazing** Mortality among seedlings protected from herbivory by a coarse (chicken wire) steel mesh was identical to that observed among uncaged seedlings (see ***L. gibsonii* mortality/survival** under **4.2 Population**

**Demography** above). Nonetheless, significant herbivory was observed in a number of surveyed plots. Herbivory was recorded on 100% of individuals in three surveyed plots: one each at Iron Hill (IH1), Iron Hill North (IHN1) and the Emu Fence. Herbivory was assessed as estimated proportion of leaves or scapes which had been grazed (usually to close to the ground). In these plots, herbivory of individual *L. gibsonii* clumps represented 15 to 100% of foliar loss (Figure 54). Complete foliar loss (100% herbivory) was observed in 35 surveyed plants. One fifth of all surveyed *L. gibsonii* adults had >20% herbivory, 16% were at least half eaten. Herbivory among seedlings was not observed as frequently: 6% of tagged seedlings had 20% or more foliar loss.

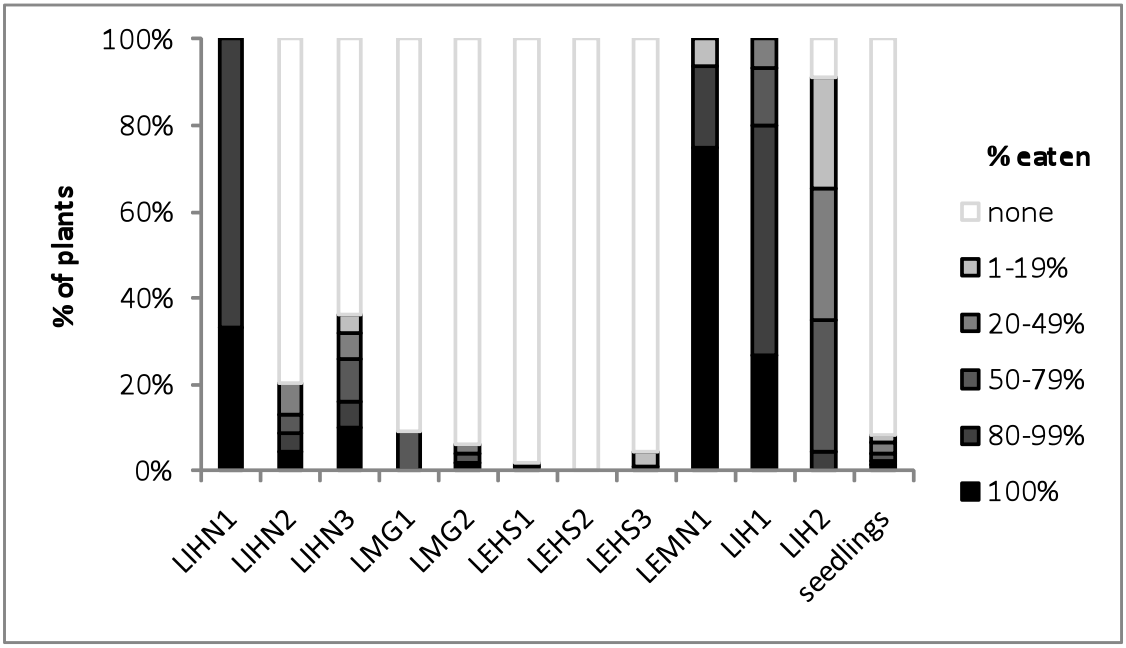



**Figure 54.** Frequency (number of plants) and intensity of maximum observed herbivory (% of foliage eaten) in mature *L. gibsonii* in each plot and in seedlings pooled across plots.

Sites with significant herbivory are located in the south and the north of the survey area, but are also lower on slopes (e.g. IH1, IHN1) or not on slopes (e.g. Emu Fence). Judging by the presence and abundance of nearby faecal scats, this grazing may be attributable to rabbits and / or goats. Macropods may also play a role.

Plants previously observed to have experienced herbivory often showed significant recovery on subsequent surveys, but sites with extensive herbivory seem to also experience frequent herbivory. While evidence for an impact of herbivory on survival rates is unclear, the evidence for an impact on reproductive output is clear. Grazed plants have their reproductive capacity reduced to exactly the same extent as they are eaten as leaves and culms are

impacted to the same extent. That is to say, plants in the most heavily grazed sites may have their reproductive output reduced to close to zero through grazing.

**Invertebrate herbivory** An unidentified scale insect (Hemiptera: Coocoidea) was observed to be abundant on *L. gibsonii* culms. In some populations (e.g. near the Emu-proof fence) they covered a large areas of the available photosynthetic surface, and in such cases are likely to significantly affect the growth rate and reproductive potential due to the parasitic, sap-sucking lifestyle of the insect.

**Fungal infections** An unidentified rust fungus has been observed on the culms of *L. gibsonii* plants from most populations, albeit usually in small numbers (1-5 culms per clump). Infected culms have been observed successfully fruiting in 'good' years. Since culms only last 2-3 years, these rusts are potentially minor parasites of *L. gibsonii*, but could potentially have a stronger effect in poor seasons, or under increased infection rates. Five species of smut fungi (four *Moreaua*, one *Heterotolyposporium*) are known to infect inflorescences of *Lepidosperma*, and have been observed in populations of *L. costale sens.lat*. in the Midwest, but not yet on *L. gibsonii*. When abundant, *Lepidosperma* smuts can sometimes have a significant impact on reproductive output, as they are systemic and destroy all florets within an inflorescence.

**Summary:**

- Interactions with other organisms play an important role in the life-cycle of both *D. masonii* and *L. gibsonii*.

- Herbivores had a negligible impact on *Darwinia masonii* plants. Seed predation (by larvae of an unidentified moth species) can be significant, although is spatially and annually variable. Positive or neutral interactions with pollinators (chiefly white cheeked honeyeaters) and seed dispersers (a number of ant species) also play a major role in *Darwinia masonii* life history.

- In *L. gibsonii*, grazing – presumed to be by goats and rabbits – can have a significant impact on growth and reproduction but was observed in only a handful of localities. Other leaf parasites, notably a rust pathogen and a scale insect also occur infrequently (and often at these same sites).

- Both the seed-eating moth, and a gall forming insect observed on *Darwinia masonii* individuals are unidentified, likely unrecognised

species and possibly specialist on *Darwinia masonii* and therefore also potentially rare and threatened species. The bract feeding beetle observed in collected *D. masonii* seed is less likely to be a specialist species.

**Recommendations:**

- Manage populations of goats and rabbits across the distribution of *L. gibsonii* and in restoration sites in particular, and monitor herbivory impacts of macropods on *L. gibsonii*.
- Ensure habitat requirements for key *D. masonii* pollinators are retained.
- Monitor and take into account the dynamics of moth impacts when collecting *Darwinia masonii* seed for restoration.
- Identify the seed-eating moth species and survey for its occurrence in co-occurring species and related *Darwinia* species.

## 4.6 RESTORATION AND TRANSLOCATION

### 4.6a Storage of propagation material for translocation

Cuttings were collected from 300 genotypes of *Darwinia masonii* and 250 genotypes of *Lepidosperma gibsonii*. All material was taken from within the mine footprint on Extension Hill and under the DRF collection permits of EHPL and BGPA. Collections were made at several times but established best when soils were moist and plant tissues were fresh and growing (i.e. mid-winter), material can then be stored and transported in cool and moist conditions. Collected material was delivered to Nuts About Natives (NAN), a specialist native plant nursery in October 2008. They reported that 385 *D. masonii* cuttings (12% of total cuttings) from 150 different genotypes (50% of genotypes) had successfully initiated after 3 months. At the same time, 815 (44%) of the 1846 pots of *L. gibsonii* divisions showed new root and shoot growth and could be considered successfully initiated. These represent 187 genotypes (75% of collected genotypes) and could be considered successfully initiated.

Both DRF species are able to be successfully initiated into cultivation, and are now stored in cultivation at NAN's nursery. These plants are maintained at NAN as an off-site genotype stock with the intention that they will be multiplied up (by taking further *D. masonii* cuttings and separating *L. gibsonii* clumps) to provide an off-site collection and perhaps ultimately to contribute to stock for population restoration. The nursery plants are maintained on unshaded external benches, regularly monitored, and watered at moderate intervals.

BGPA has made a number of additional collections, using the same techniques and keeps a small number of genotypes of both species in glasshouses at Kings Park for experimental purposes. Here, *L. gibsonii* grows vigorously, and flowers, under watered glasshouse conditions, and is easily split and repotted to create larger number of individuals (clones). *Darwinia masonii* cuttings survive and flower but have not shown the same degree of vigour in their growth, *Lepidosperma gibsonii* appears to be susceptible to a moth whose subterranean caterpillars (likely a native species and possibly present at Mt Gibson) consume dead and older live, leaf material. *Darwinia masonii* cuttings appear to prefer lower humidity levels than may often occur in glasshouse conditions. Seedlings established from *D. masonii* seeds derived from experimental studies are also potted up and growing in Kings Park glasshouses. These appear to grow with slightly greater vigour than cuttings.

Glasshouse plants of both species experimentally exposed to drought conditions do not appear to be able to enter or recover from a dormant, drought-mode state equivalent to that observed in field plants through late summer and autumn (see **4.5c Drought study**). Propagated plants planted in field translocation trials in winter did appear to achieve and recover from this dormant state in the following summer and winter periods.

While the use of nursery stock from cuttings or clump separation is a proven and suitable technique for population restoration, its drawbacks imply that investigation into the use of seed as a restoration resource for *D. masonii* and *L. gibsonii* are worth continuing. The drawbacks of greenstock include its infrastructure, resource and time demands (pots, potting media, glasshouse bench space, irrigation, pest management, time and expertise to establish cuttings, plant out, etc) as well as implications for genetic selection and diversity. Selection in propagation – i.e. with survival of plants better suited to glasshouse, but not necessarily field, conditions – can lead to a loss of genetic diversity and capacity. In terms of numbers, collection and establishment of genotypes numbering in the (low) hundreds is feasible and demonstrated, larger numbers may be possible but with diminishing returns in terms of required effort. Finally, the translocation of large and/or unbalanced numbers of genetic clones means that some genotypes may become grossly over-represented in restoration, which should ideally aim to replicate source levels of genetic diversity. The most effective way to ensure reinstallation of genetic diversity without creating artificial imbalances in genotype representation is to use seeds as a restoration source, either from collected seed or soil seedbanks.

In this area recommendations differ for *D. masonii* and *L. gibsonii*. Seed of *L. gibsonii* has proven difficult to collect and germinate and is likely to continue as such, however *D. masonii* seed is produced in larger numbers and more easily collected. As germination of treated fresh or standard stored seed of *D. masonii* is also low, this immediate approach is not recommended for restoration. However, germination of buried seed retrieved after 9 months of burial in field soils and then treated with smoke water reached 90% (see **4.3d Seed bank demography**). This suggests three possibilities: 1) It is technically feasible to explicitly follow this approach, exhuming bagged seeds after a period of burial in field soils, for germination in pots for planting as seedling greenstock; 2) Trialling a process of broadcasting of *D. masonii* seeds into field restoration areas, followed by application of smoke or smoke chemicals after some period, and which does seem likely to lead to the emergence of seedlings after some time; 3) Continued research into cues responsible for the pattern identified in burial trials may enable replication of these in seeds under lab conditions (e.g. by storing seeds under alternating warm/ hot temperatures and following this with a period of cool and moist conditions and the application of smoke) and cued seed could then be applied to restoration areas ready to germinate – at higher rates.

**Summary:**

- Techniques for the successful collection, establishment, maintenance and propagation of both *D. masonii* and *L. gibsonii* have been proven at both BGPA and an independent specialist nursery.

- Proven propagation techniques involve greenstock production from cuttings (*D. masonii*) or separated clumps (*L. gibsonii*).

- Both species can persist as tube-stock when stored outside in hygienic nursery conditions and watered through dry periods. *L. gibsonii* may show improved growth under more humid glasshouse conditions.

**Recommendations:**

- *ex situ* collections of live plant and seed material and multiple (>100 for live plants) genotypes should be monitored and maintained and supplemented as required.

- Seed collections made for restoration purposes should be viability checked and maintained in standard, pest-free, temperature and humidity controlled seed banks.

- Propagation of live plant material from wild collections and nursery stock likely pose the most cost effective approach for the short-medium term storage and production of plants for restoration purposes.

- Collection and storage of seed for restoration purposes may yet prove effective and is relatively cheap, however allowance must be made for the likely ultimate rate of seed germination, difficulty of collection (for *L. gibsonii*) and the potential cost (in time and money) of developing seedlings from seed.

- Uncertain and low seed production rates, and poor return in terms of demonstrated germination rates (to date) means that this approach is not yet recommended.

- For *D. masonii*, further research into seedling production under lab, glasshouse or field conditions appears promising and may provide a preferable approach to providing a genetically diverse and numerous source of restoration plants.

### 4.6b Translocation methods

Plants from the BGPA collection, supplemented by material previously cultivated at NAN (from BGPA collections) were used in translocation trials at Extension Hill with acceptable survival rates (as described in **4.5b Translocation study**). Evidence from the *D. masonii* pilot watering trial (also see 4.5b) indicates that *D. masonii* survival may be approximately doubled by irrigation in the initial years, although the two trials commenced in years differing markedly in their total rainfall receipt.

The trials performed demonstrate successful establishment and survival of both *D. masonii* and *L. gibsonii* in the rocky/gravelly loams of the Extension Hill range. While it is yet possible that some substrate attribute essential to growth and survival of these species may be missed in a regular replacement of gravel/rocky loam over waste rock, and these should be confirmed in restoration trials, the indications that this would succeed are good.

Potential localities for translocation (as opposed to restoration) of populations have been identified and mapped in section **4.5a** (**Abiotic associations**).

Plans for studies of plants planted into reconstructed substrates and designed to identify optimal soil and subsurface features for the growth and survival of *D. masonii* and *L. gibsonii* were contingent upon the commencement of mining and the provision of trial areas with trial substrate materials derived from the mining process. These are still to take place.

**Summary:**

- Trial translocation of propagated cuttings of *D. masonii* and split clumps of *L. gibsonii*, planted into field substrates in early winter and watered only at planting have proven successful.

- Attributes and localities of potential translocation sites within the Mt Gibson-Extension Hill range have been identified.

**Recommendations:**

- Experiments manipulating restoration substrates using mine waste components or other available and appropriate materials are recommended as mining construction commences.

## 4.7 *EX SITU* CONSERVATION

### 4.7a Seed storage

Batches of 1000 filled seeds of each of *Darwinia masonii* and *L. gibsonii* have been deposited at each of the WA Seed Technology Centre in the Botanic Gardens and Parks Authority at Kings Park, the DEC-operated Western Australian Threatened Flora Seed Centre, and Kew Garden's Millennium Seedbank at Wakehurst Place in the UK. These three facilities are premier global and national seed storage facilities.

Viability of long-term stored *L. gibsonii* seeds has not been tested due to its recent collection date, however *D. masonii* seed collected from 2004 and stored for three years appears to retain equivalent levels of viability when compared to seed collected (and simultaneously tested) in 2007. The soil seedbank strategy of both species strongly suggests that seed viability is likely to persist though storage under standard seed storage conditions for many years.

**Summary:**

- Batches of 1000 filled seeds of each of *Darwinia masonii* and *L. gibsonii* have been deposited at each of three, Australian and international, conservation seed storage facilities.

### 4.7b Germplasm storage

Germplasm storage techniques were investigated using standard approaches from excised seed embryos for both *D. masonii* and *L. gibsonii*, and shoot cuttings for *D. masonii*. The medium used for in vitro propagation was basal medium as per Bunn (2005) supplemented with BAP 0.15 µM, pH 6 and 6 gL-1 agar.

For *D. masonii*, shoot cutting material was trialled from 12 individuals representing 5 populations in a total of 35 separate 120 ml culture tubes. After a period of three months, all 35 tubes had initiated root and stem tissue and were growing well and multiplying (Figure 55). Culture lines are being maintained successfully in culture at room temperature with alternating cool storage (short to medium term storage).

**Figure 55**. *Darwinia masonii* in tissue culture (bar = 20 mm)

For *L. gibsonii*, tissue culture was attempted via embryo extraction in an experiment combining investigation into the role of heat shock on *L. gibsonii* seeds. Fruits were soaked in water for 24 hours to soften up the endosperm, then surface sterilised in 1% bleach for 20 minutes and rinsed in sterile water three times for approximately 3-5 minutes each. Embryos were then extracted under a binocular microscope in a laminar flow cabinet and plated on a special media of ½ MS + GA3 + Zeatin (6g per litre Agar & 20g per litre Sucrose). Prior to imbibing water, fruits were split into control and multiple heat treatment samples, with the latter exposed in a temperature controlled oven to 100°C for a period of 10 to 90 minutes for the heat shock treatment. Each of the seven treatments included a total of 16 embryos. Plated embryos were incubated @ 15°C in dark conditions examined for growth. Embryos with growing root and shoot systems were transferred to culture tubes and maintained under the same conditions as per *D. masonii* (above).

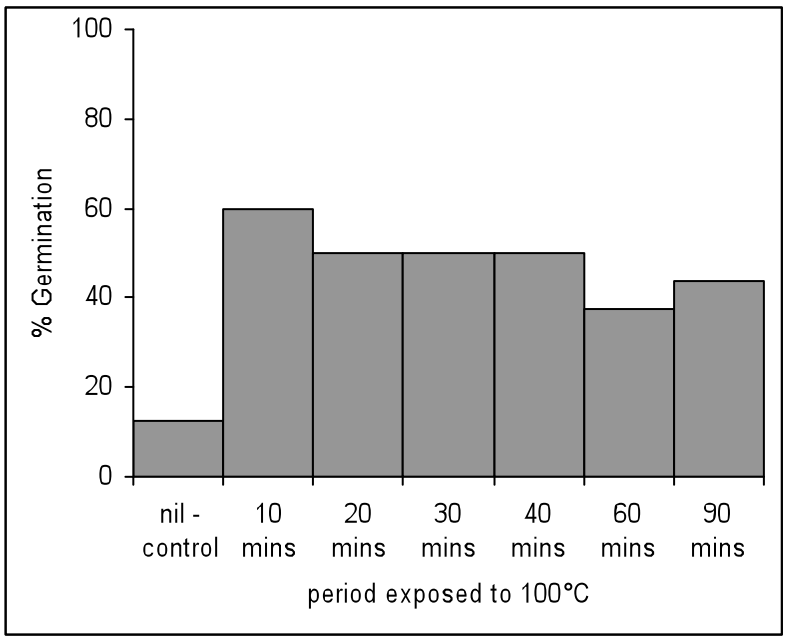



**Figure 56.** Germination rates (including to establishment of roots and leaf shoots) for seeds of *Lepidosperma gibsonii* exposed to varying periods of heat treatment.

An average of 49% of excised *L. gibsonii* embryos exposed to temps of 100°C produced roots and shoots and survived to establish successfully in tissue culture (Figure 56). Less than a quarter of this proportion of seeds not exposed to high temperatures germinated and established, and there is some limited indication that exposure to 100°C for longer periods may lead to lower establishment.

**Summary:**

- *in vitro* culture, with root initiation has been achieved with multiple genotypes of both *Darwinia masonii* and *Lepidosperma gibsonii*, using stem tissue and embryo extraction respectively.
- Culture lines can be maintained in culture with alternating room temperature / cool storage (for short to medium term storage).
- Cryostorage is an option for long-term storage of key clonal germplasm if required.
- Micropropagation is feasible should it be required as a propagation option for both species.
- Genotypes of both species are stored as live plants at two locations off-site (including a significant collection of Extension hill genotypes of both species)

- Genotypes of both species are additionally stored as seed at three secure locations off-site, representing a total of 3000 seeds of each species.

**Recommendations:**

- *ex situ* collections of live plant and seed material and multiple (>100 for live plants) genotypes should be monitored and maintained.

- The effectiveness of *ex situ* storage of germplasm in a variety of forms is demonstrated for both species, but live plant collections likely pose the most cost effective approach for the short-medium term.

- Collection and storage of seed as an *ex situ* conservation measure may also be effective, and is relatively cheap, however allowance must be made for the likely ultimate rate of seed germination, difficulty of collection (for *L. gibsonii*) and the potential cost (in time and money) of developing seedlings from seed.

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**Appendix B**
***Darwinia masonii* Translocation Site Selection Matrix and Site Location**

# Darwinia Translocation Program – Site Selection Matrix – Iron Hill Offsets - 2021

| Site Number | Previous Disturbance | Access for construction, fencing, maintenance and monitoring | Future Disturbance Likelihood | Within Mt Gibson Ranges | Substrate | BGPA Likelihood | Capacity | Rating (1 – 5, 5 being the highest) |
|---|---|---|---|---|---|---|---|---|
| 2 | Yes | Yes (at closure Year 3) | Yes – Iron Hill Proposal | Yes | Suitable | Suitable | Approx 300 | 4 (Not being considered for 2017) |
| 4 | Yes | Yes | Nil | Yes | Suitable | Yes | Additional Approx 200 to existing 165 Alive | 5 |
| 5 | No | No | Near Iron Hill Proposal | Yes | Suitable | Suitable | - | 1 (Not being considered for 2017) |
| 6 | Yes – bare ground amongst existing vegetation and historical drilling | Access for everything except fencing – will need to trial individual plant mesh guards | Nil | Close proximity | Suitable | Not mapped this far | Approx 200 | 4 |
| 7 | Yes | Yes | Unlikely | Yes | Suitable | Likely | - | 2 – (Not being considered for 2017) |
| 8 | No – NVCP required | Possibly not | Unlikely | Yes | Suitable | Likely | - | 1 (Not being considered for 2017) |
| 11 | Yes – some clearing in existing vegetation above historical track and evidence of historical fire. Evidence of dozer / track marks | Yes – area above track includes regrowth which plants could be placed among | Unlikely | Yes | Suitable – good mixture of BIF rocks and fines | Suitable | Approx 500 - 600 | 5 |
| 12 | Yes | Yes | Nil | Yes | Relatively suitable | Less likely | Approx 200 | 3 (Not being considered for 2017) |
| 13 | No – NVCP Required, high volume of regrowth on existing track and potential plot area | Yes | Nil | Yes | Suitable | Likely | Approx 300 – 600 | 3 (Not being considered for 2017) |
| 14 | Yes | Yes | Nil | Yes | Suitable | Likely | Additional Approx 300 – 350 to existing 173 Alive | 5 |
| 15 | No – NVCP Required, high volume of regrowth on existing track and potential plot area | Yes | Nil | Yes | Suitable | Likely | Approx 300 – 600 | 3 (Not being considered for 2017) |
| 16 | Yes | Yes | Nil | Yes | Suitable | Likely | Approx 300 | 5 (Not being considered for additional plantings in 2017) |
| 17 | Yes – drill pad access track. Evidence of disturbance at the Southern and Western area of access track | Yes | Nil | Yes | Suitable – Upper area at South West area of track is suitable. Some very hard BIF and numerous rocks. | Likely | Approx 400 – 500 (Irrigation system will support another 420 so may require modification to cater for an increase in plants) | 4 |
| 25 | Yes | Yes – though the initial track is rough/steep and will be difficult for water truck to climb | Unlikely | Yes | Very rocky, surface soils stripped from historical disturbance. Too hard to dig and not enough suitable soil | Yes | 100 at most due to difficult digging | 3 (Not to be considered for 2017 plantings) |
| IH1WRL | Yes – WRL | Yes | Nil | Yes | Suitable | Not mapped | 613 (planted 2019) | 5 |
| IH2WRL | Yes – WRL | Yes | Nil | Yes | Suitable | Likely | 300 | 5 |
| IH3WRL | Yes – WRL | Yes – adjacent to landfill site | Nil | Yes | Suitable | Likely | 300 | 5 |
| IH1South | Yes – haul road out of Iron Hill pit | No – abandonment bund | Nil | Yes | Less suitable – more fines | Less likely | 200 | 3 |
| IH2South | Yes – haul road out of Iron Hill South pit | Yes | Nil | Yes | Less suitable – more fines | Less likely | 200 | 3 |

KEY: = Priority Translocation Site

**Appendix C:**
***Lepidosperma gibsonii* Translocation Proposal**

(Approved 2017)

Government of **Western Australia**
Department of **Parks and Wildlife**
**Science and Conservation Division**

Your ref:
Our ref:
Enquiries: Niall Sheehy
Phone: (08) 9219 9513
Email: niall.sheehy@dpaw.wa.gov.au

Mr. Matthew Hamilton
Mount Gibson Iron Limited
PO Box 55
West Perth WA 6872

Dear Mr. Hamilton

**APPROVAL FOR TRANSLOCATION PROPOSAL FOR: *Lepidosperma gibsonii***

I would like to inform you that the translocation proposal for the above species of declared rare flora has been approved by the Department of Parks and Wildlife's Director of Science and Conservation Division.

Please ensure that the proposal is followed accordingly and the progress of the translocation is reported to the Department annually.

Yours sincerely

Niall Sheehy

Niall Sheehy
A/FLORA ADMINISTRATIVE OFFICER
for the DIRECTOR GENERAL

13 February 2017

# MOUNT GIBSON MINING LIMITED

# PROPOSAL FOR THE TRANSLOCATION OF LEPIDOSPERMA GIBSONII

**Version 2.0**
**Date of Revision: January 2017**

Mount Gibson Mining Limited
ABN 32 074 575 885

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# TABLE OF CONTENTS

**1. Introduction ..... 1**

**1.1 Species recovery actions to date ..... 1**
**1.2 Purpose of Proposal ..... 2**
**1.3 Evidence of Current Translocation Success ..... 2**
**1.4 Proponent ..... 3**

**2. Background ..... 4**

**2.1 Description ..... 4**
**2.2 Biology ..... 4**
2.2.1 General ecology ..... 4
2.2.2 Seed germination and fire ecology ..... 5
**2.3 Conservation status ..... 5**
**2.4 Population size and distribution ..... 6**
**2.5 Research to date ..... 10**
**2.6 Translocation commitments ..... 11**

**3. Translocation Proposal ..... 13**

**3.1 Site selection considerations ..... 13**
3.1.1 Suitable habitat ..... 13
3.1.2 Logistics of providing supplementary water ..... 15
3.1.3 Source and availability of live plant material ..... 15
3.1.4 Prospective exploration and mining areas ..... 15
**3.2 Translocation areas ..... 16**
**3.3 Translocation timelines ..... 19**
**3.4 Plant Source and Translocation methodology ..... 20**
**3.5 Maintenance and monitoring ..... 21**
**3.6 Criteria for success ..... 21**
3.6.1 Short term criteria (approx. first 2 years) ..... 22
3.6.2 Medium and Long term criteria (Year 3 and Beyond) ..... 22
**3.7 Reporting of Monitoring Results ..... 22**
**3.8 Funding ..... 22**

**4. Endorsement ..... 23**

**5. References ..... 24**

**6. Appendices ..... 25**

Appendix 1 *Lepidosperma gibsonii* Draft Recovery Pan ..... 26
Appendix 2 *Lepidosperma gibsonii* and *Darwinia masonii* Conservation and Restoration Research Report ..... 27

## FIGURES

FIGURE 1: CONFIRMED *LEPIDOSPERMA GIBSONII* RECORDS ON TENEMENTS WITHIN AND ADJACENT IRON HILL (RECORDS = BLUE DOTS). ..... 8
FIGURE 2: DPAW RECORDS OF LEPIDOSPERMA SPP AS OF FEBRUARY 2016 (RED SHOWN AS CONFIRMED *L.GIBSONII* RECORDS). ..... 9
FIGURE 3 MAPPED PROBABILITIES OF THE PRESENCE OF *LEPIDOSPERMA GIBSONII* (BGPA 2010) VS ACTUAL RECORDS OF *L. GIBSONII* LOCATIONS ..... 14
FIGURE 4 POTENTIAL TRANSLOCATION SITES FOR *LEPIDOSPERMA GIBSONII.* SITE TYPES (A, B, C, D) ARE DESCRIBED BY SECTION 3.2 ..... 18

## TABLES

TABLE 1 *LEPIDOSPERMA GIBSONII* POPULATION RECORDS (SUBSET OF RECORDS ON MT GIBSON RANGES TENEMENTS) ..... 7
TABLE 2: STATUS OF *LEPIDOSPERMA GIBSONII* HELD AT NUTS ABOUT NATIVES NURSERY AS OF NOVEMBER, 2015. ..... 15
TABLE 3 NOMINAL TIMELINE FOR TRANSLOCATION ACTIVITIES ..... 19

# 1. Introduction

*Lepidosperma gibsonii* (R.L. Barrett) occurs within a genus of flowering plants in the family Cyperaceae. Most of the species in this genus are endemic to Australia.

*Lepidosperma gibsonii* appears to be restricted to the mid-west region of Western Australia where it occurs in the vicinity of the Mt Gibson Ranges, which are located approximately 80 kilometres (km) northeast of Wubin and 350 km north east of Perth. Within the Mt Gibson Ranges, *L. gibsonii* prefers slopes or gullies that provide increased water availability during rainfall events. The populations occurring outside of the Mt Gibson Ranges are associated with low granite outcrops or breakaways and loamy flats in close proximity to the breakaways.

*Lepidosperma gibsonii* is specially protected under the *Wildlife Conservation Act 1950* (WA) and is ranked as Vulnerable (VU) in Western Australia under International Union for Conservation of Nature (IUCN) 2001 Red List criterion D2.

MGM currently mine hematite ore from the Extension Hill operations in the Mt Gibson Ranges. MGM is proposing to extend the mine life of the Extension Hill operations at the Iron Hill hematite ore deposits located immediately south of Extension Hill in the Mt Gibson Ranges. The Iron Hill deposits contain an estimated 5 – 7 million tonnes of hematite ore and would extend the current mine life by approximately 2 – 3 years.

The Iron Hill deposits proposal involves the disturbance of 87 ha of land within a 112 ha Development Envelope. Disturbance would involve a reduction in abundance of *Lepidosperma gibsonii,* representing 2% of the population. Implementation of this translocation proposal will assist in offsetting the removal of *Lepidosperma gibsonii* due to implementation of the Iron Hill Proposal.

## *1.1 Species recovery actions to date*

Mount Gibson Mining (MGM) has been mining on Extension Hill at the Mt Gibson Ranges since 2010. Prior to this time, MGM and Extension Hill Pty Ltd (EHPL) went through an extensive formal Environmental Impact Assessment (EIA) via Part IV of the *Environmental Protection Act 1986* (WA) and after referral and assessment under the EPBC Act, Ministerial Statement No 753 (MS 753) was granted in October of 2007.

Condition 7-1 (4) of MS753 requires that the proponent develop:

"*measures to offset the direct impacts of the proposal on the local population of* the species *by regeneration, re-establishment or translocation of additional plants or sub-populations on suitable un-impacted areas of banded ironstone formations in the Mt Gibson area.*"

The implementation of the BGPA research program, *Lepidosperma gibsonii* Interim Recovery Plan and the *Lepidosperma gibsonii* Recovery Plan did, in part, satisfy that condition.

MGM went through an extensive formal EIA via Part IV of the *Environmental Protection Act 1986* (WA) and after referral and assessment under the EPBC Act, Ministerial Statement No 1045 (MS1045) was granted in December 2016. Condition 7 of MS 1045 describes the requirement to implement an offset for 863 *Lepidosperma gibsonii* which may be impacted by the proposal. This Translocation Proposal will support the implementation of that condition.

Recovery Action #8 in the Interim Recovery Plan (2008 – 2012; Appendix 1) is "*to undertake translocations as part of the Lepidosperma gibsonii Research Program*". This has occurred in trials and those outcomes are summarised in Section 2.5. The Interim Recovery Plan remains in place until the (full) Recovery Plan is approved by the CEO as authorised by MS753.

The draft Recovery Plan developed by MGM (in consultation with Parks and Wildlife) also builds on the actions of the Interim Recovery Plan with a specific recovery action to "*develop a restoration program*".

The Draft Recovery Plan describes the actions and tasks to develop a restoration program, thus:

> "*The modelled habitat and recorded groups of plants has increased the known areas of occurrence and abundance of the population. Because of this, direct or extensive plant translocations may not be necessary in the short to medium term while the abundance and area of occurrence is at current levels.*"

The Iron Hill Deposit Mine Development will reduce the abundance of *L. gibsonii* (2% of the total population records). Given that there have been successful collections, propagation and maintenance of *L. gibsonii* plant material under nursery conditions, and that translocation of *L. gibsonii* plants was demonstrated to be successful over the short term (20 months; Ruoss 2013) then it is feasible that this species can be collected, propagated and translocated (taking into account the research outcomes of BGPA 2010).

This Translocation Proposal provides a method for the establishment of *L. gibsonii,* initially sourced from Iron Hill, onto restored areas. It effects the implementation of offsets to the removal of individuals within the proposed Iron Hill Development Envelope and complements the recovery actions in the Interim Recovery Plan and will further inform the Draft Recovery Plan.

## 1.2 Purpose of Proposal

The purpose of this translocation program is to collect and generate plant specimens in order to translocate *L. gibsonii* using the same methodologies developed by BGPA (2010; Appendix 2). These actions will utilise the outcomes of the BGPA (2010) research by using the learnings gained and applying at a broader scale. It will also enact the requirements of the species' interim recovery plan.

This Proposal provides the level of information and format defined in the Department of Parks and Wildlife's Corporate Policy Statement No. 35 *Conserving Threatened Species and Ecological Communities* (2015a) and Corporate Guideline No. 36 *Recovery of Threatened Species through Translocation and Captive Breeding or Propagation* (2015b), and taking into account the Australian Network for Plant Conservation translocation guidelines (Vallee *et al.* 2004) and IUCN Guidelines for Reintroductions and Other Conservation Translocations (2013).

## 1.3 Evidence of Current Translocation Success

Translocation trials of 780 *L. gibsonii* plants (BGPA 2010) were divided into three replicate sites at four treatment sites containing different substrates from each other (i.e. loam/clay, sand, gravel and rock). *Lepidosperma gibsonii* showed between 60-70% survival (9 months after planting) when grown on gravel or rocky substrates (BGPA 2010). No supplementary watering had been provided. The translocated plants were grown alongside *Acacia cerastes*.

A doctoral thesis (Ruoss 2013) complements the BGPA (2010) research findings. Ruoss (2013) set up trials that showed that translocated *L. gibsonii* seedlings resulted in 59% and 63% survival (20 months after planting) when grown on a rocky ridge or gravel slope, respectively. Low levels of success occurred when seedlings (collected clumps divided and grown to seedlings in nursery) were grown on sand plain (16% survival) or clay plain (2% survival) substrates. The greatest mortality occurred over the first summer and from thereafter survival was relatively stable up until 20 months (end of the study).

Monitoring at the Ruoss plots occurred in May 2016 by MGM environmental personnel and the overall survival rate was an average 9% for BIF gravel and 22% for BIF Rock. For this reason, the long term success criteria for individual plant survival has been reduced from 70% to 50% (Section 3.6.2). Whilst the success criteria of previous trials is well below 50%, it should also be noted that this trial did not appear to consider variables such as shade and solar radiation as the sites were placed on an open plain with full overhead exposure. This Translocation Proposal will build on those learnings and consider suitable habitat as outlined by Section 3.1 and also consider watering or irrigation with the expectant result being that survival rates will increase.

## 1.4 Proponent

The proponent for this Proposal is:

***Mount Gibson Mining Limited***

*Address*

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# 2. Background

## 2.1 Description

*Lepidosperma gibsonii* is a fine-leaved herb (sedge), and grows up to 0.6 - 0.7 m high (Meissner and Caruso 2006, Barrett 2007). Its pale green culms are terete, scarcely finely ribbed and fully erect, and grow up to 45 cm tall. Rhizomes are compact and short. Leaves are angular; distinctly diamond-shaped and compressed; deep green when fresh turning pale green to glaucous when semi-dormant. The leaves grow up to 45 cm long, 0.73 mm wide and 0.58 mm thick. Bracts are tan and glabrous. Flowers are simple or with one small branch at the base, and grow up to 51 mm long and 3.5 mm wide, with 4 - 8 spikelets. Spikelets grow up to 3.2 mm long. The upper flower is bisexual and the lower flower is functionally male. The flower bracts may be up to 39 mm long. The flowers' have glumes with opaque pale margins grading to a rusty red keel. The style base is continuous with the ovary, caducous and approximately 0.55 mm long. Anthers are up to 2 mm long including anther filaments (up to 2.4 mm long) and apical appendage (up to 0.38 mm wide) (Meissner and Caruso 2006, Barrett 2007).

*Lepidosperma gibsonii* flowering to seed production occurs over an 18 month period. Flower development starts in late winter to early spring. Seeds are cream but become mottled brown with age, are smooth and have three prominent ribs. Seeds are approximately 1.4 mm long and 0.9 mm wide (Meissner and Caruso 2006, Barrett 2007).

## 2.2 Biology

### 2.2.1 General ecology

*Lepidosperma gibsonii* appears to be restricted to the mid-west region of Western Australia where it occurs in the vicinity of the Mt Gibson Ranges, which are located approximately 80 kilometres (km) northeast of Wubin and 350 km north east of Perth. Within the Mt Gibson Ranges, *L. gibsonii* prefers slopes or gullies that provide increased water availability during rainfall events. The populations occurring outside of the Ranges are associated with low granite outcrops or breakaways and loamy flats in close proximity to the breakaways. In the majority of locations from where *L. gibsonii* has been recorded, the soils range from skeletal on the upper slopes often in association with the margins of larger areas of exposed ironstone, Banded Ironstone Formation (BIF) or granitic outcropping to deeper, sandy loams on the side slopes and gully floor. The geographical extremes of the populations are less than 8 km apart, thus making the species a restricted and narrow endemic.

Although the known distribution of *L. gibsonii* appears to be restricted, it demonstrates traits of strong ecological resilience, namely:

1. It is a re-sprouting species and therefore capable of surviving fire and grazing to a greater extent than a seeder species;
2. The species demonstrates vigorous subsoil rhizome sprouting indicating that the plant can respond to seasonal moisture and is probably capable of producing a shoot to flower in one year; and
3. Clump size and branching patterns indicate that individual clumps are long lived, likely for multiple decades and potentially longer.

Overall the species is probably long-lived, resilient to fire and grazing, and disease tolerant. Initial research by BGPA suggest that the species is water rather than nutrient limited, with rapid growth rates in standard soil mixes indicating that the substrate may be less important than water harvesting attributes (BGPA 2010). Although the report also indicated a survival rate of between 60-70% without irrigation.

*Lepidosperma gibsonii* flowering to seed production occurs over an 18 month period (BGPA, 2010). Flower development starts in late winter to early spring followed by a period of dormancy over summer until May-June when the flowers mature and release their pollen. *Lepidosperma gibsonii* is wind pollinated and therefore has a high outcrossing rate (i.e. a multilocus outcrossing rate of 91.7%) compared to selfing. Seeds mature in the same year and are released over a two week window around mid-October (BGPA 2010).

As the rainfall in the region is unreliable, *L. gibsonii* is likely to respond opportunistically (at least with vegetative growth) to rainfall events (i.e. tropical cyclonic summer rainfall events and southern winter cold fronts).

### 2.2.2 Seed germination and fire ecology

Large scale production of seedlings of *L. gibsonii* via germination of fresh or stored seed involves seed coat nicking or removal, or retrieval of seed buried for months or years (BGPA, 2010). Preliminary results of *in situ* seed burial trials, which commenced in January 2009, indicate complex germination / dormancy strategies. A combination of physical degradation of the seed coat, and seasonal temperature cycles results in seeds cycling in and out of dormancy. In addition smoke-related physiological responses and heat treatment responses are evident in the seed germination of this species. Germination rates of 60% were achieved by manual seed coat removal followed by a heat treatment. Regardless, *L. gibsonii* seed germination for broadscale restoration remains unsolved.

BGPA (2010) concluded that "*as seed germination remains difficult for L. gibsonii, propagation from plant collections is the best viable option, however methods to grow plants from seed embryos in tissue culture have been developed, and provide another, more time-consuming solution.*"

There is evidence of seedling recruitment of *L. gibsonii* in areas recently burnt by fire, although limited inter-fire recruitment is also evident. *Lepidosperma gibsonii* adults show some resilience to fire with only partial death of clumps (BGPA 2010). An experimental fire conducted by BGPA (2010) in May, 2009 resulted in the death of between 48% and 56% of adults. The remainder resprouted from buds surviving within the burnt clumps. Seedling recruitment (average of 4.2 seedlings produced per pre-fire adult) was also observed five months later (October, 2009). Mortality among seedlings can reach 76% over the first summer and winter following fire, but thereafter averages 3% per year (a similar rate of mortality to adults). Reproduction then commences in seedlings at six years of age (BGPA 2010).

## *2.3 Conservation status*

*Lepidosperma gibsonii* is specially protected under the *Wildlife Conservation Act 1950* (WA) and is currently ranked as Vulnerable D2 under the International Union for Conservation of Nature (IUCN) criteria.

The species is not listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

## 2.4 Population size and distribution

Using data from the most recent and accurate records (Table 1), the size of the *L. gibsonii* population is now conservatively estimated to comprise approximately 60,000 to 70,000 plants (Table 1 indicates this to be 75, 236). . The most comprehensive data for many populations range in accuracy, and most of it is at least eight years old, so the present size of the population may differ. Note that the size of the population when the Interim Recovery Plan was prepared in 2008 comprised 45,013 mature plants (DEC, 2008), which means that the current data available indicates that the known population size has, because of new records, increased by over 30% since 2008.

Approximately 39% of the estimated population are from slopes and gullies within the Mt Gibson Ranges. Of the balance of the population, the majority of records are associated with breakaways and granite outcrops within 4 km of the Ranges, and currently recorded to occur in six discrete groups.

*Lepidosperma gibsonii* was originally reported as associated with the following vegetation communities on the Mt Gibson Ranges (Bennett, 2000):

- 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.
- T3 - Dense Thicket dominated by *Acacia assimilis*, *Allocasuarina acutivalvis* subsp. *prinsepiana* and *Melaleuca nematophylla* over Low Shrubland of *Hemigenia* sp. Paynes Find and *Hibbertia crassifolia* in loam pockets in 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.
- HS1 - Low Heath of *Ptilotus obovatus* with emergent shrubs of *Acacia stowardii* and *Calycopeplus paucifolius* over Herbs in loamy clay large amongst large boulders.
- Emu proof fence sub-population - Low Woodland of *Eucalyptus kochii* subsp. *plenissima*, *Eucalyptus kochii* subsp. *horistes* over Tall Open Scrub dominated by *Allocasuarina acutivalvis*, *Acacia aneura*, *Micromyrtus clavata* and *Acacia acuminata* on clayey loamy soil.
- Sub-populations C and D - *Allocasuarina acutivalvis* subsp. *prinsepiana*, *Melaleuca uncinata*, *Acacia assimilis* subsp. *assimilis*, and *Melaleuca nematophylla*.
- Sub-population E - Low Open Woodland of *Eucalyptus leptopoda* subsp. *arctata* with occasional *Allocasuarina acutivalvis* subsp. *prinsepiana* over a Tall Open Woodland *Melaleuca uncinata* and *Acacia aneura* var. *aneura* over a Tall Scrubland dominated by *Acacia masliniana* over a Low Shrubland dominated by *Micromyrtus clavata* and *Thryptomene cuspidata* over a Very Open Herbland of *Ecdeiocolea monostachya* and *Hyalosperma glutinosum* subsp. *glutinosum*.
- Sub-population F - *Allocasuarina acutivalvis* subsp. *prinsepiana*, *Melaleuca uncinata*, *Acacia assimilis* subsp. *assimilis*, and *Melaleuca nematophylla*.

The *L.gibsonii* records on Iron Hill occur with floristic groups FG12 and FG17 as mapped by Eco Logical (2016). Those vegetation types are known to consist of:

- FG12 – *Allocasuarina acutivalvis*, *Melaleuca nematophylla* and *Grevillea obliquistigma* shrubland over *Cheilanthes adiantoides* ferns and,
- FG17 - *Eucalyptus loxophleba* subsp. *supralaevis* and *Callitris columellaris* open woodland over *Acacia acuminata*, *Allocasuarina acutivalvis* and *Acacia anthochaera* tall open shrubland over *Dodonaea inaequifolia*, *Eremophila clarkei*, *Grevillea paradoxa* and *Philotheca brucei* open shrubland over *Amphipogon caricinus* var. *caricinus* very open grassland.

In other physiographic settings, such as plains and breakaways (see Figure 2), it occurs with other vegetation types.

**Table 1 *Lepidosperma gibsonii* population records (subset of records on Mt Gibson ranges tenements)**

| | *Lepidosperma gibsonii* Population | | *Lepidosperma gibsonii* Cumulative Effect | |
|---|---|---|---|---|
| Baseline | No. Individuals | % Individuals | No. Individuals | % Individuals |
| **Confirmed total records** at and surrounding the Mt Gibson Ranges (Figure 2) | 49,472* | 100% | - | - |
| Confirmed Records **East** of Great Northern Hwy (GNH) at and surrounding the Mt Gibson Ranges (Figure 2) | 25,764 | 52% | - | - |
| Predicted Impacts | | | | |
| Approved Mine Operations at Extension Hill (MS753) | 8,071 (7,886 mature) | 16% | 8,934[1] | 18% |
| Within Iron Hill Deposits (MS1045) | 863 (118 mature) | 2% | | |
| Other areas at and surrounding the Mt Gibson Ranges | 40, 538 (33,253 mature) | 82% | 40, 538 | 82% |

* All values are based upon the records held by MGM which are confirmed by DPaW (see Figure 4).

[1] Of these only 820 have been taken to date as per MS753.

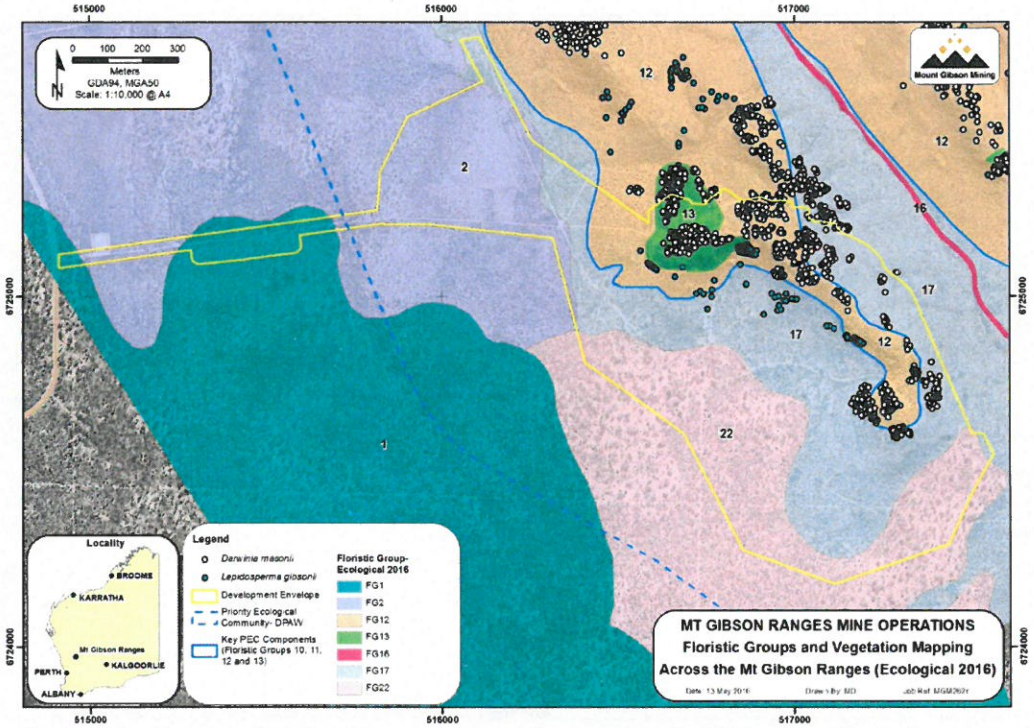


**Figure 1: Confirmed *Lepidosperma gibsonii* records on tenements within and adjacent Iron Hill (records = blue dots).**

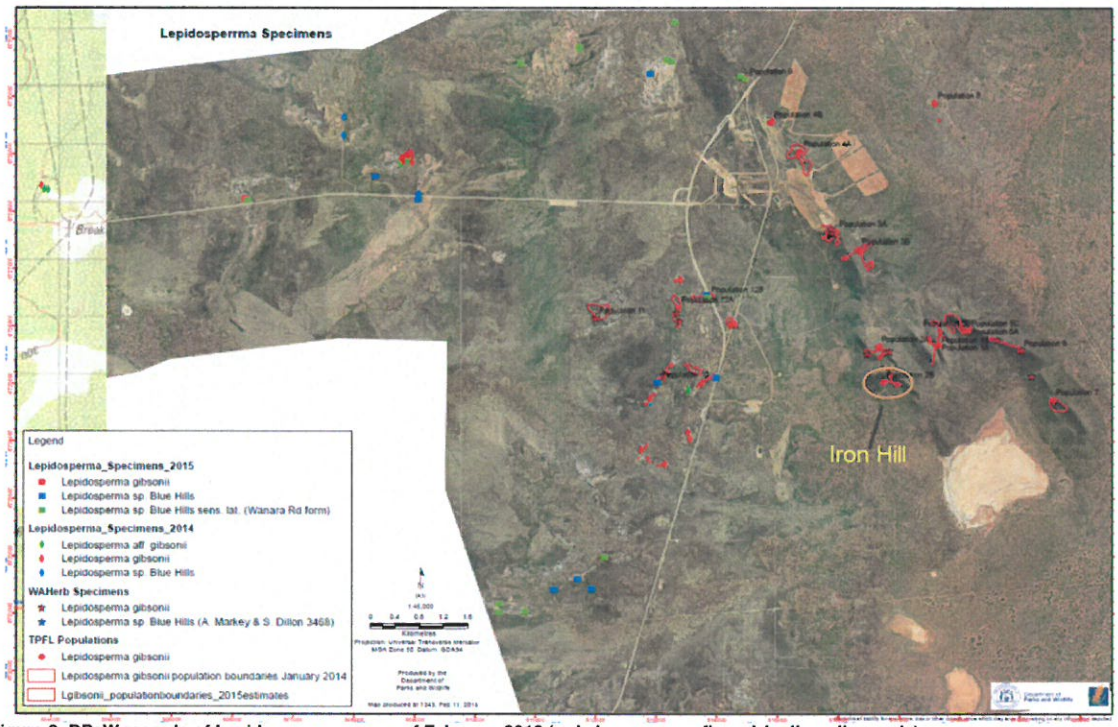


**Figure 2: DPaW records of Lepidosperma spp as of February 2016 (red shown as confirmed *L.gibsonii* records).**

## 2.5 Research to date

An extensive research program was conducted by Botanic Parks and Gardens Authority (and funded by MGM and EHPL) between 2007 and 2010 (BGPA, 2010; Appendix 2). The program focussed on seven broad research aspects:

1. Conservation genetics: Population structure, comparison with other species, phylogeny and clonality.
2. Population demography: Fire, demography, tools for monitoring plant demographic changes.
3. Breeding/recruitment biology: Seed research, seed production, soil seed bank, phenology, genetic analysis of breeding systems and dispersal.
4. Population Viability Analysis: Modelling of population persistence (Not completed and information not available for use in this Proposal).
5. Environmental interactions and plant health: Biotic and abiotic associations, habitat requirement assessment, ecophysiology, impacts of associations on plant health, and tools to monitor plant health.
6. **Restoration and translocation**: Reconstruction of habitat, propagation, translocations, and tools to monitor rehabilitation, dust, and water table lowering.
7. Ex-situ conservation propagation for long-term seed storage, and cryostorage.

Specific to the focus of this proposal, the findings of a translocation study (Research aspect 6 above) was summarised by BGPA (2010) as follows:

> *"This experiment involved planting nursery stock of D. masonii and L. gibsonii – established respectively from cuttings and separated clumps, together with seedlings of Acacia cerastes (a local species with a P1 conservation status).*
>
> *Plantings occurred in four sites with differing field soil substrates which included 1) deep red loam/clay plains east of Extension Hill – a material potentially available in abundance for restoration as it underlies most of the planned waste rock dump, 2) white-yellow sands of sandplains west of Extension Hill and 3) gravelly and 4) rocky loams of the north Extension Hill slope and ridge (Table 30).*
>
> *Three 10m x 10m replicate plots per site were cleared and fenced before planting (Table 30). A total of 780 plants of each species were planted in July/August 2009, with 65 per plot. Monitoring of these plants started after one month and is ongoing at 3 month intervals. Monitoring has included demographic (survival, health, height, fecundity) and ecophysiological parameters (leaf gas exchange and plant water status – measured via a Li- 6400 gas analyser; LI-COR Inc, Lincoln, Nebraska, USA and a Scholander-type pressure chamber; Wescor Inc., Logan, UH, USA).*
>
> *By April 2010 (9 months after planting), results showed clear differences among substrates. Acacia cerastes established on all of the four substrates, but least successfully at the Clay site (Figure 38). Darwinia masonii and L. gibsonii demonstrated a greater specificity for substrate type with survival successful only in the BIF Rock and BIF Gravel substrate.*

> *While occasional L. gibsonii plants persist on the other sites they show very limited vigour and survival prospects. In terms of mean plant health and height, plants of all three species performed better growing on BIF rock and BIF gravel loams than on the clay and sandy substrates. Measurement of the physiological attributes of these plants – rates of photosynthesis, transpiration and water potential – confirm the poor performance of D. masonii and L. gibsonii on sand and clay.*"

*Lepidosperma gibsonii* showed between 60-70% survival (9 months after planting) when grown on gravel or rocky substrates (BGPA 2010). No supplementary watering had been provided. The translocated plants were grown alongside *Acacia cerastes*.

A doctoral thesis (Ruoss 2013) further complements the BGPA (2010) research findings. Ruoss (2013) found that translocated *L. gibsonii* seedlings resulted in 59% and 63% survival (20 months after planting) when grown on a rocky ridge or gravel slope, respectively. Low levels of success occurred when seedlings were grown on sand plain (16% survival) or clay plain (2% survival) substrates. The greatest mortality occurred over the first summer and from thereafter survival was relatively stable up until 20 months (end of the study).

Monitoring at the Ruoss plots occurred in May 2016 by MGM environmental personnel and the overall survival rate was an average 9% for BIF gravel and 22% for BIF Rock. For this reason, the long term success criteria for individual plant survival has been reduced from 70% to 50% (Section 3.6.2). Whilst the success criteria of previous trials is well below 50%, it should also be noted that this trial did not appear to consider variables such as shade and solar radiation as the sites were placed on an open plain with full overhead exposure. This Translocation Proposal will build on those learnings and consider suitable habitat as outlined by Section 3.1 and also consider watering or irrigation with the expectant result being that survival rates will increase.

BGPA (2010) recommended that restoration/translocation areas for *L. gibsonii* should "*be shaped as slopes or gullies oriented with lower radiation receipt*" and include "*treatments varying shade and moisture.*"

BGPA (2010) also found this species to be susceptible to grazing by goats or rabbits. Therefore protection from grazing should be managed.

## 2.6 Translocation commitments

Condition 7-1 (4) of MS753 requires that the proponent develop:

> "*measures to offset the direct impacts of the proposal on the local population of* the species *by regeneration, re-establishment or translocation of additional plants or sub-populations on suitable un-impacted areas of banded ironstone formations in the Mt Gibson area.*"

The implementation of the BGPA research program, *Lepidosperma gibsonii* Interim Recovery Plan and the *Lepidosperma gibsonii* Recovery Plan did in-part satisfy that condition.

This proposal intends to meet the offset requirements of condition 7-8 of MS1045 for the Iron Hill Deposit Mine Development on *Lepidosperma gibsonii*. This translocation program will further inform recovery actions in the Interim Recovery Plan and future restoration efforts.

Recovery Action #8 in the Interim Recovery Plan (2008 – 2012; Appendix 1) is "*to undertake translocations as part of the Lepidosperma gibsonii Research Program*". This has occurred and

outcomes are summarised in Section 2.5. The Interim Recovery Plan remains in place until the (full) Recovery Plan is approved by the CEO as authorised by MS753.

The draft Recovery Plan developed by MGM (in consultation with Parks and Wildlife) also builds on the actions of the Interim Recovery Plan with a specific recovery action to "*develop a restoration program*".

The Draft Recovery Plan describes the actions and tasks to develop a restoration program, thus:

> "*The modelled habitat and recorded groups of plants has increased the known areas of occurrence and abundance of the population. Because of this, direct or extensive plant translocations may not be necessary in the short to medium term while the abundance and area of occurrence is at current levels.*"

The Iron Hill Deposit Mine Development will reduce the abundance of *L. gibsonii* individuals in the wild (less than 2% of the total population). Given that there have been successful collections, propagation and maintenance of *L. gibsonii* plant material under nursery conditions, and that translocation of *L. gibsonii* plants was demonstrated to be successful over the short term (20 months; Ruoss 2013) then it is feasible that this species can be collected, propagated and translocated (taking into account the research outcomes of BGPA 2010) as a means of offsetting the Iron Hill Deposits proposal development effects.

# 3. Translocation Proposal

The proposal is based on taking plant material, propagating them under nursery conditions and establishing them in translocation sites on suitable habitat and rehabilitation areas.

## *3.1 Site selection considerations*

MGM will identify preferred sites, taking into consideration the following variables:

1. Suitable habitat and potential rehabilitation areas
2. Logistical access of providing supplementary water to plant material used in at least one translocation site
3. Source and use of live plant material
4. Longevity of land use

### 3.1.1 Suitable habitat

BGPA (2010) research identified the most suitable habitat for *L. gibsonii* to be gullies and slopes, with the following characteristics, each showing differing probabilities of *L. gibsonii* presence when considered on its own:

- Winter solar radiation 2pm <0.4 $w.m^{-2}.hr^{-1}$ (80%)
- Elevation > 340 m (29.5%)
- Slope (13.6%)

The high association of *L. gibsonii* with habitat that has relatively low receipt of light and heat is reflected by its requirement for low solar radiation. BGPA (2010) suggest that such habitats include gullies and slopes with low radiation receipt. Using this data, a heat map showing a probability of L. gibsonii presence on the Mt Gibson Ranges as well as on the surrounding areas overlain with the actual mapped locations of *L. gibsonii* plants is shown in Figure 3.

Some sites may provide existing shade from surrounding plants/trees (i.e. provision of an overstorey), representative of the same community type, and will also reduce solar radiation. Within the disturbed sites different species may be selected with canopies of differing densities, and ease of propagation, to accompany the translocated *L. gibsonii* plants. They will be introduced either by seed from brush or direct seeding, or as seedlings, and may be done at the earliest possible time to provide shade during the first two summer periods. The accompanying species will be representative of those species in adjacent vegetation. In addition, sites will be selected in areas alongside or within established native vegetation in undisturbed areas, and on slopes, which receive less solar radiation.

Translocation trials also demonstrate greater *L. gibsonii* survival rates when planted in rocky or gravel substrates in comparison to clay or sand (BGPA 2010, Ruoss 2013). This is characteristic of the habitat in which the species occurs within and surrounding the Mt Gibson Ranges. Therefore, translocation areas will be selected with rocky or gravel substrates.

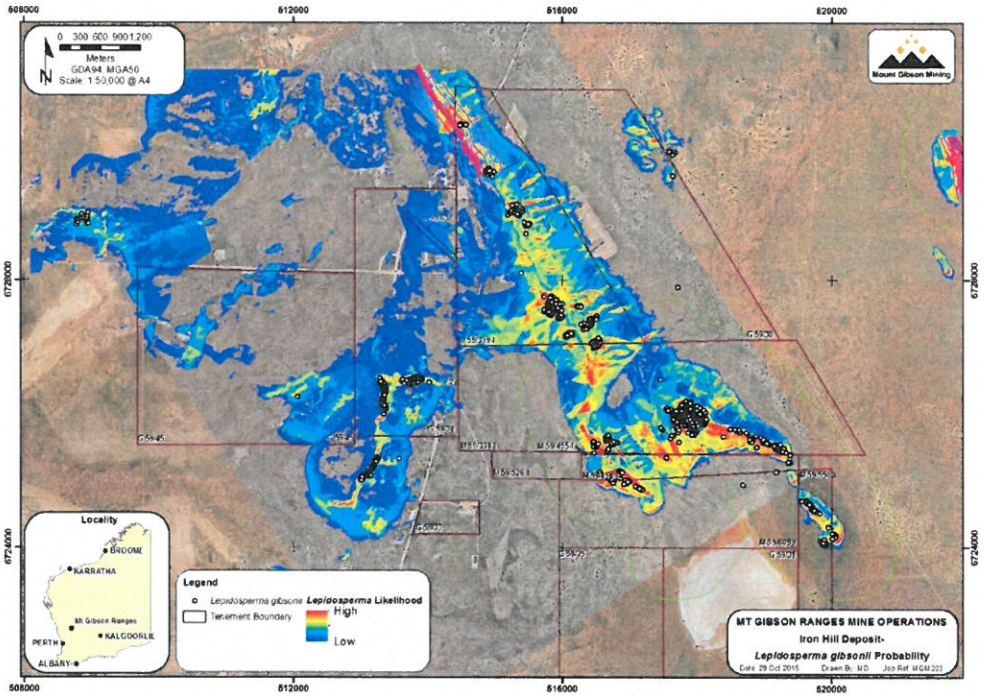


**Figure 3 Mapped probabilities of the presence of *Lepidosperma gibsonii* (BGPA 2010) vs actual records of *L. gibsonii* locations**

### 3.1.2 Logistics of providing supplementary water

The logistics of being able to get water to a translocation site will be closely considered. Steep and narrow tracks or areas of distance from a track make the accessibility of getting water tanks and cartage to an area difficult. In consultation with mine site personnel, the logistics and accessibility will be taken into consideration.

### 3.1.3 Source and availability of live plant material

There are 744 *L. gibsonii* plants sourced from Extension Hill stock (TPFL 3A and 4A) currently held at the nursery (Table 2).

A "Permit to Take" application was submitted in order to collect additional plant material from up to 1000 genotypes initially sourced from TPFL 2A and 2B (Iron Hill North and Iron Hill) during the winter of 2016. Clumps have been collected in accordance with Permit 200-1516 during the winter of 2016 and clones are currently being grown in a NIASA nursery. Approximately 943 genotypes were collected from. The actual number of clones is yet to be determined.

Individuals from which divisions would be sourced will be taken into account when determining the location of the area in which to transplant them. The actual location of translocation sites and the source material to be used at each site will be determined in collaboration with DPaW. MGM recognises the genetic composition of the species across the Range as outlined by BGPA (2010) and will allocate source material to appropriate translocation sites for the purpose of trying to maintain this genetic composition. Source material from populations 3A and 4A would be prioritised for translocation sites 1, 3, 10, 18 and 19. Whilst source material from populations 2A and 2B would be prioritised for all other potential translocation sites (Figure 4). This will maintain the genetic dissimilarity between the northern aspects of the range (Extension Hill South to Extension Hill North) and the southern aspects of the range (Iron Hill North to Mt Gibson South). No translocation sites are proposed at Mt Gibson Saddle where BGPA (2010) identifies genetic isolation from other populations.

**Table 2: Status of *Lepidosperma gibsonii* held at Nuts about Natives nursery as of November, 2015.**

| Nursery Code | TPFL | Date struck | Total # genotypes collected | Total # genotypes (Feb, 2016) | Total # clones (Feb, 2016) |
|---|---|---|---|---|---|
| MGML | 3A | Oct, '08 | 217 | 147 | 634 |
| MGML | 4A | Oct, '08 | 33 | 19 | 71 |

### 3.1.4 Prospective exploration and mining areas

In order to maintain the benefits of successful translocations in the future, proposed translocation sites will be chosen to avoid potential future mineral exploration or mine development (as best known at the time of site selection). MGM and EHPL geologists and mine planners will be consulted to determine the likelihood of a specific area being required for future programs that would require land disturbance; although the risk of this happening is reduced, it cannot be eliminated entirely. It is understood that any proposed disturbance to *L. gibsonii* plants growing on translocation areas may require a Permit to Take.

## 3.2 Translocation areas

MGM have identified four types of prospective translocation areas:

**Type A areas** - Supplementing the original *Darwinia masonii* translocation trial plot (Translocation site #04; Augmentation)

In this location, although *Lepidosperma gibsonii* was not planted previously, there is suitable existing disturbed ground for the translocation of *Lepidosperma gibsonii.* Translocations of *Lepidosperma gibsonii* in this area would supplement the previous success of BGPA trials with *Darwinia masonii.*

**Type B areas** - Translocation onto disturbed areas within the zone of predicted habitat (Introduction or Re-introduction)

Previously disturbed areas within the zone of predicted habitat will include:

- Drill pads and tracks that occur on slopes; or
- Historic tracks that may have led through gullies.

This type of translocation would directly replicate the methodology of the BGPA translocation trial and take into account site selection considerations (Section 3.1 above). The goal will be to establish a group of approximately 400 individuals per area and replicate the success of the original trial on previously disturbed areas.

**Type C areas** - Translocation onto natural areas within the zone of predicted habitat (Augmentation)

This type of translocation would occur in natural areas and utilise the shade of established plants. A Native Vegetation Clearing Permit may need to be obtained prior to undertaking this part of the translocation proposal. Clearing of native vegetation will be minimised by selecting areas under the canopy of native vegetation.

As these areas would be within the zone of predicted habitat, they may or may not occur alongside the existing population.

**Type D areas** - Translocation onto areas near the zone of predicted habitat but potentially prospective for *L. gibsonii* (Introduction)

These areas are currently beyond the habitats of known occurrence (BGPA 2010) but provide contingency for translocations where Type B or C areas are not found; types B & C are preferable.

**Type S areas** - Translocation onto established waste rock landforms for seeding trials and/or seedling trials

The Extension Hill waste rock landform and the Iron Hill waste rock landform (to be created in the future) are composed of rock sourced from BIF geologies and will be re-seeded with native species. Provided an area is selected with the right slope and solar aspect (Section 3.1.1) these landforms may prove to be suitable habitat for the propagation of *Lepidosperma gibsonii.*

Potential translocation sites and areas are shown in Figure 4.

Upon approval of a Translocation Proposal, the proponent will lodge a translocation plan to DPaW that details the sites and their location which are most suitable (as per Section 3.1) and shows how the following criteria are met:

- on land that is already cleared or disturbed on predicted habitat at the Mount Gibson ranges;
- the number of mature plants and the source material that each proposed translocation site would support
- confirm:
    - the feasibility of irrigation and fencing at the sites;
    - proposed completion criteria; and
    - measures for protection of the plants from threats.

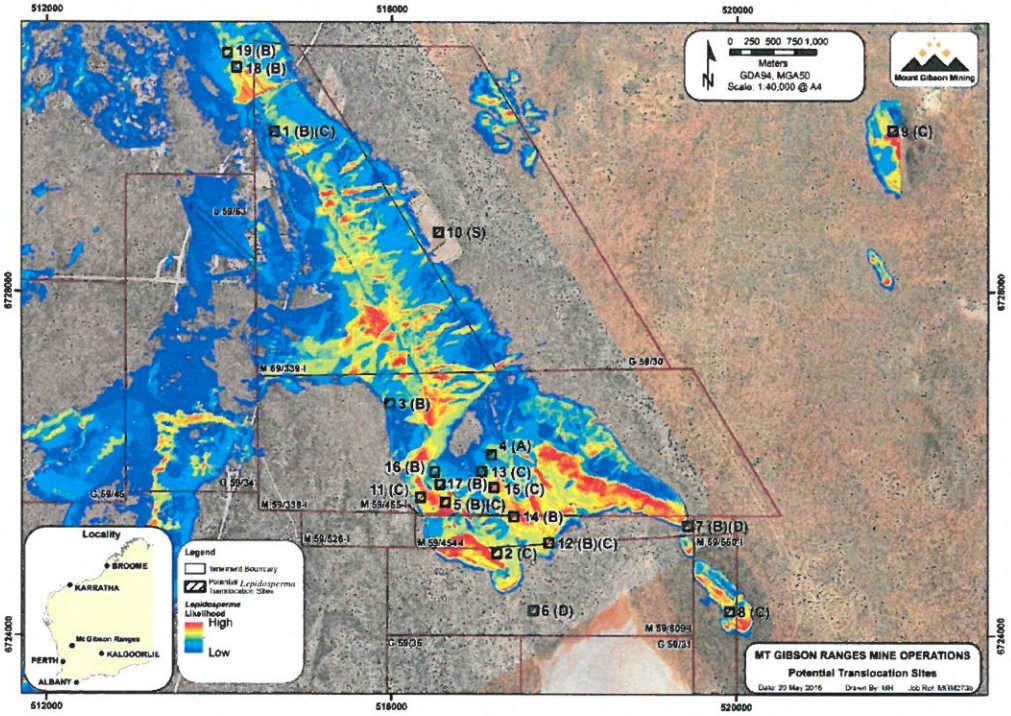


**Figure 4 Potential Translocation sites for *Lepidosperma gibsonii*. Site types (A, B, C, D) are described by Section 3.2**

## 3.3 Translocation timelines

It is anticipated that translocations will be established on a yearly basis for a period of two years as shown in Table 3. It is envisaged more than 2000 individuals may be translocated, with approximately 400 or more being planted per site (7 or more sites). However this may change depending on the site specific characteristics of the DPaW approved Translocation Plan. The planting work will occur between 2017 and 2018 with monitoring occurring thereafter (Table 3).

The program and schedule for preparing, establishing and planting nominated sites will be advised by MGM and EHPL to DPaW annually. This will also include location, substrate, elevation, slope, and source population.

Many more individuals will be propagated as required for the translocations. Typically, the aim will be to maintain one clone per genotype in the nursery as contingency. This is necessary because, if any translocation areas result in significant loss of individuals, then there are still genotypes available from the original *L. gibsonii* plants.

The nominal timeline for the translocation activities is described in Table 3. Annual reporting by the proponents at the conclusion of Phase 1 (March 2018) will also make recommendations including about how, or whether or not to progress to Phase 2.

**Table 3 Nominal timeline for translocation activities**

| Activity | Timeline |
|---|---|
| **2016 (Preparation year)** | |
| Application for Permit to take DRF (granted) | May 2016 |
| Collection of Year 1 plant material (completed) | Winter-Spring, 2016 |
| Nursery propagation of Year 1 collected material (underway) | Winter 2016 - Autumn 2017 |
| Selection of two to four suitable sites in Year 1 areas | Summer 2016 / 2017 |
| NVCP application and permit (if required) | Summer 2016/17 |
| **2017 (Year 1; Phase 1)** | |
| Site preparation of Year 1 sites | Autumn 2017 |
| Selected sites planted with approx. 400 individuals | Early winter 2017 |
| Collection of Year 2 plant material for other areas (if required for Phase 2) | Winter – Spring, 2017 |
| Selection of one to three suitable sites for Year 2 areas | Winter 2017 |
| Nursery propagation of Year 2 collected material (if required) | Winter 2017 - Autumn 2018 |
| Weekly monitoring of Year 1 sites (month 1 and 2) | Spring 2017 |
| Monthly monitoring of Year 1 sites | Summer Dec 2017-Feb 2018 |
| **2018-19 (Years 2 & 3; Phase 2)** | |
| Site preparation of Year 2 translocation sites (if required) | Autumn 2018 |
| Selected translocation sites planted with approx. 400 individuals | Winter 2018 |
| Annual monitoring of Year 1 sites | Spring 2018 |
| Weekly monitoring of Year 2 sites (month 1 and 2) | Winter-Spring 2018 |

| Activity | Timeline |
|---|---|
| Monthly monitoring of Year 2 sites | Summer Dec,2018-Feb,2019 |
| Annual monitoring of Year 2 sites | Spring 2018 |
| Annual monitoring of all sites | Spring 2019 - 2023 |
| Five year monitoring of Year 1 translocation sites | Spring 2022 |
| Five year monitoring of Year 2 translocation sites | Spring 2023 |

## 3.4 Plant Source and Translocation methodology

Site selection, collection of the origin plant material and application for a Native Vegetation Clearing Permit (NVCP) if required will occur over the period between winter to summer of 2016. It is preferable to MGM to leave established native vegetation in place to provide cover and habitat for proposed translocated plants; however, small areas may need to be cleared allow access and to conduct ground work to develop plots.

Ground preparation may be required at translocation sites. Disturbed areas may be ripped to reduce the effects of compaction that may have occurred as a result of their previous use. Translocations into natural areas will not require any site preparation other than digging holes in which to put the plants.

*Lepidosperma gibsonii* plants will be required from *in situ* sources at the Mt Gibson Ranges. Plant material will be propagated in pots at a NIASA certified nursery such as Nuts about Natives, Karnup (hygiene-certified) or Drylands nursery, Geraldton (uses hygiene-certified soils) and transported to Extension Hill mine site at the time of planting. The plants will then be planted by hand, and placed in previously prepared holes, approximately 0.3 m in depth. A fertiliser (for Australian natives) may be added to supplement the soil in each hole. Green or dry brush collected from surrounding vegetation may be placed around the plants of at least one translocation area to:

- Serve as a mulch;
- Provide protection from grazing;
- Shade the plants from direct sunlight; and
- Re-introduce the seed from other species growing in adjacent vegetation.

The plants will be watered in and then drip irrigation may be made available to each plant in at least one site. Those plants will be irrigated for one hour, twice per month (or as frequently as needed) for the first two summers and possibly winter period (if required, due to drought or a very dry preceding or trailing winter period).

Based on outcomes of the BGPA translocation research program, more than one area with differing moisture (e.g. irrigation vs no irrigation) or shade treatments (e.g. brush, established vegetation, accompanying species) may be used to further develop the methodology. On natural areas, the planting area will be restricted to one area. This approach builds on *L. gibsonii* translocation research conducted to-date (i.e. BGPA 2010).

All sites will be fenced to exclude any goats and rabbits and the type of fencing will be determined based on specific site characteristics.

Each plant will be tagged and given a unique identifier that links it back to propagation and source information.

Depending on the progress of the first phase of the program, additional sites may be required for a phase 2 planting. If all sites with differing treatments are successful then a phase 2 planting may not be required.

The size of the sites and number of resulting plants may also be supplemented in the following year to meet success criteria (defined in Section 3.6).

## 3.5 Maintenance and monitoring

The survival and condition of plants in each site (approx. 100 $m^2$) will initially be recorded. Plants will be monitored weekly for the first eight weeks and spot irrigated if required (subject to rainfall events) to assist with early survival and plant establishment.

After two months and during the summer period, translocation sites will be visited on a monthly basis by site personnel to monitor and record plant survival for a period of two years, conduct maintenance of irrigation equipment and pumps, check the integrity of fences, check water levels in water tanks and assess for herbivory (check effectiveness and maintenance of fencing if the plants are at risk of extensive herbivory).

After two years, *L. gibsonii* populations will be monitored on an annual basis for survival and condition for the period of five years after their translocation. Second generation plants will be recorded and tagged if evident and monitored thereafter.

After five years, monitoring may continue to measure survival, flowering and recruitment on an annual basis until such time that long-term criteria for success have been met for three consecutive years.

Introduction of weeds is a risk due to regular visitation of personnel and vehicles to translocation sites. This risk will be mitigated by use of existing minesite weed hygiene procedures such as vehicle wash downs for new vehicles arriving on site and regular washing of vehicles permanently located on site. Individuals are also responsible for ensuring their clothing and footwear is weed free.

## 3.6 Criteria for success

The aim of this translocation program supports the conservation status of *L. gibsonii* by returning individuals on the Mt Gibson Ranges.

The implementation of the translocation program will be considered a success if population survival and establishment equals:

### 3.6.1 Short term criteria (approx. first 2 years)

| Success Criteria | Criteria for adaptive management |
|---|---|
| Greater than 200 individuals in each site (>50% survival) | Less than 200 individuals in each translocation site (<50% survival) |

Adaptive management: If monitoring outcomes reflect that the short-term success criteria have not been met, supplementary plantings of cuttings/seedlings may occur in the following year. Maintain clones of each genotype in the nursery for contingency.

### 3.6.2 Medium and Long term criteria (Year 3 and Beyond)

| Success Criteria | Criteria for adaptive management |
|---|---|
| Greater than 200 individuals in each translocation site (>50% survival). | Less than 200 individuals in each translocation site (<50% survival) |
| Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL. | Flower production and seed set of surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL. |
| Recruitment of second generation individuals' that are equivalent to recruitment rates of individuals growing naturally within the nearest TPFL. | Recruitment of second generation individuals' is less than recruitment rates of individuals growing naturally within the nearest TPFL. |

Adaptive management: If monitoring outcomes reflect that the short-term success criteria have not been met, supplementary plantings of cuttings/seedlings may occur in the following year. Maintain clones of each genotype in the nursery for contingency.

## *3.7 Reporting of Monitoring Results*

The location, substrate, elevation, slope, compass orientation and source population and then survivorship will be recorded and reported for each translocation site. The presence of flowering, fruiting and seed production on the translocated plants, and presence of new recruits (including tag identification numbers and GPS readings) in the near vicinity of the translocation sites will also be recorded.

Medium and long term monitoring and reporting will include an assessment of the number of plants that are flowering, have seed set and number of recruits in natural areas within the nearest population (TPFL).

Annual monitoring reports and a final report at the end of the project will be provided to the Flora Administrative Officer, Species and Communities Branch, Department of Parks and Wildlife.

## *3.8 Funding*

Funding of this translocation program relating to Iron Hill plant stock will be the responsibility of MGM.

# 4. Endorsement

This Proposal is endorsed by representatives of the Mount Gibson Mining (the proponent) and Extension Hill Proprietary Limited (the tenement holder).

I hereby certify that to the best of my knowledge, the information within this Translocation Proposal is true and correct and addresses the requirements of *Corporate Guideline No. 36 Recovery of Threatened Species through Translocation and Captive Breeding or Propagation* (Department of Parks and Wildlife, 2015b).

*Signature* *Date*

Mr Troy Collie
Project Director, Environment and Approvals
Mount Gibson Iron Limited

*Signature* *Date*

Mr Ben McLernon
Manager, Environment & Community
Extension Hill Proprietary Limited
(Tenement Holders)

# 5. References

Botanic Gardens and Parks Authority (BGPA) (2010). *Darwinia masonii and Lepidosperma gibsonii Conservation and Restoration Research. An integrated research program into the ex situ and in situ conservation, restoration and translocation requirements of Darwinia masonii and Lepidosperma gibsonii May 2007 – June 2010.* Unpublished report prepared by Botanic Gardens and Parks Authority (Kings Park and Botanic Garden) for Mount Gibson Mining Limited and Extension Hill Pty Ltd, Perth, WA.

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Vallee, L., Hogbin T., Monks L., Makinson B., Matthes M. And Rossetto M. (2004*) Guidelines for the Translocation of Threatened Australian Plants.* Second Edition. The Australian Network for Plant Conservation. Canberra, Australia.

# 6. Appendices

# Appendix 1 *Lepidosperma gibsonii* Draft Recovery Pan

# Appendix 2 *Lepidosperma gibsonii* and *Darwinia masonii* Conservation and Restoration Research Report

**Appendix D:**
***Lepidosperma gibsonii* Translocation Site Selection Matrix**

# Lepidosperma Translocation Program – Iron Hill Offsets – Site Selection Matrix – 2021

| Site Number | Existing Disturbance | Access for construction, fencing, maintenance and monitoring | Future Disturbance Likelihood | Within Mt Gibson Ranges | Substrate | BGPA Likelihood | Existing shade from surrounding tress, regrowth, solar radiation, slope | Capacity | Rating (1 – 5, 5 being the highest) |
|---|---|---|---|---|---|---|---|---|---|
| 2 | Yes | Yes (at closure Year 3) | Yes – Iron Hill Proposal | Yes | Suitable | Suitable | Unknown | Approx 300 | 4 (not considered for 2017 plantings) |
| 4 | Yes | Yes | Nil | Yes | Suitable | Lower likelihood | Inadequate protection from solar radiation – north sloping face and inadequate shade | Approx 300 | 3 (not considered for 2017 plantings) |
| 5 | No | No | Near Iron Hill Proposal | Yes | Suitable | Suitable | Unknown | - | 1 |
| 6 | Yes – bare ground amongst existing vegetation and historical drilling | Yes – though would need to trial mesh fencing for individual plants | Nil | Close proximity | Suitable | Not mapped this far | Some shade, though not south west facing | Approx 200 | 3 (Need to re-check again for potential 2017 plantings) |
| 7 | Yes | Yes | Unlikely | Yes | Majority of substrate in this area appears hard and difficult to dig | Likely | A search across this entire area by foot at this south eastern extent did not reveal any applicable locations – solar radiation considered too high | - | 1 (not considered for plantings in 2017) |
| 8 | No – NVCP required | Possibly not | Unlikely | Yes | Suitable | Suitable | Unknown – this area requires further investigation though it is probably too remote to access | - | 1 |
| 11 | Yes – track below and evidence of historical disturbance from fire and/or dozer tracks | Yes | Nil | Yes | Suitable - good mixture of BIF rocks and fines | Suitable – within red and yellow area of BGPA zone | Yes – west facing slope, numerous shrubs and plants from regrowth which could provide shade for plantings around the base of plants | Approx 500 - 600 | 5 |
| 12 | Yes | Yes | Nil | Yes | Relatively suitable | Suitable | No – there is a lack of area which could be identified that may provide protection from solar radiation | - | 1 (not considered for plantings in 2017) |
| 13 | Yes – however NVCP required to clear regrowth from historical tracks and drill pad | No | Nil | Yes | Suitable | Relatively Suitable | Slope is north east facing and unlikely to provide enough protection from solar radiation | - | 1 (not considered for 2017 plantings) |
| 14 | Yes – area above existing plot which appears to be overgrown disturbance may also be suitable for Lepidosperma | Yes | Nil | Yes | Suitable – option to import supplementary topsoil with buckets if necessary | Likely | Yes – slope is west facing and trees from regrowth may provide some shade if planted around the base | Approx 400 - 500 | 5 |
| 15 | Yes – however NVCP required to clear regrowth from historical tracks and plot area | No | Nil | Yes | Suitable | Likely | Slope is north east facing and unlikely to provide enough protection from solar radiation | - | 1 (not considered for 2017 plantings) |
| 16 | Yes | Yes | Nil | Yes | Suitable | Relatively Suitable | North facing and lack of suitable shade | - | 1 (not considered for 2017 plantings) |

## Lepidosperma Translocation Program – Iron Hill Offsets – Site Selection Matrix – 2021

| Site Number | Existing Disturbance | Access for construction, fencing, maintenance and monitoring | Future Disturbance Likelihood | Within Mt Gibson Ranges | Substrate | BGPA Likelihood | Existing shade from surrounding tress, regrowth, solar radiation, slope | Capacity | Rating (1 – 5, 5 being the highest) |
|---|---|---|---|---|---|---|---|---|---|
| 17 | Yes | Yes | Nil | Yes | Suitable | Relatively Suitable | East facing and open, not suitable for Lepidosperma | - | 3 |
| 24 | Yes – Historic drill pad, overgrown mixture of dead and live plants | Unlikely - distant location and steep rocky access will make driving to the site difficult | Unlikely | Yes | Suitable - very rocky surface and sub-surface, enough fines for digging holes, though will need to be selective | Suitable | Yes – SSW facing slope, enough shade from the canopy of regrowth and surrounding vegetation | Approx 300 | 3 (Not considered for plantings in 2017) |
| 26 | Yes – tracks in a number of directions | Yes – tank on side of the road, tracks which can be fenced from the sides | Unlikely | Yes | Suitable – rocky/ gravel interspersed with clay and silts | Suitable | Yes – South West facing, surrounded by trees and higher canopies | Approx 500 - 1000 | 5 |
| 27 | Yes – evidence of fire and very old overgrown clearing | Yes – tank on side of track and room for fencing in cleared areas | Unlikely | Yes | Suitable – rocky/ gravel interspersed with clay and silts | Suitable | Yes – South facing and there is some surrounding trees / shade | Approx 300 - 500 | 5 |
| 28 | Yes – evidence of open areas which appear to be old drill tracks | Yes – tank / pumps on side of track, though would need very long pipe to reach site of planting. Small areas could be fenced. | Unlikely | Yes | Suitable – rock/gravel, hard to dig now but should be softer in winter | Suitable | Yes – south west facing, high canopy, some exposed areas but may still be suitable | Approx 300 – 400 | 4 |
| IH1WRL | Yes – WRL | Yes | Nil | Yes | Suitable | Not mapped | South West facing, exposed with limited established vegetation, not suitable for Lepidosperma | - | 2 |
| IH2WRL | Yes – WRL | Yes, with minor modifications | Nil | Yes | Suitable | Suitable | South facing, exposed | Approx 400 | 3 |
| IH3WRL | Yes – WRL | Yes | Nil | Yes | Suitable | Suitable | South facing, exposed | Approx 300 | 3 |
| IH1South | Yes – WRL | Yes, with minor modifications | Nil | Yes | Suitable | Suitable | South West facing, trees and canopy along either side of rehabilitated haul road | Approx 300 | 3 |
| IH2South | Yes - WRL | Yes, with minor modifications | Nil | Yes | Suitable | Not mapped | South West facing, exposed with limited established vegetation, not suitable for Lepidosperma | - | 2 |

KEY: = Priority Translocation Site

**Appendix E:**
**Correspondence with Parks and Wildlife**

## Matthew Hamilton

**From:** Atkins, Ken <Ken.Atkins@DPaW.wa.gov.au>
**Sent:** Wednesday, 25 May 2016 5:03 PM
**To:** Matthew Hamilton
**Cc:** lara.jefferson@enperitus.com; Chant, Alanna; Troy Collie; Kuehs, Janine
**Subject:** RE: Darwinia masonii Translocation Proposal v4

Thanks Matt for outlining your proposal and identifying the translocation sites.

As agreed at the meeting, the outline proposed below is acceptable to the Department.

As discussed also, I would appreciate being informed of the actual methodology at the time, that is, whether seed and or cuttings are being used, and any site preparation works being proposed. During this trial phase, site disturbance should be minimised in less disturbed locations, with the implementation methodology being agreed once the trial work is completed.

Regards

_____

Dr Ken Atkins
Manager, Species and Communities Branch
Department of Parks and Wildlife
Locked Bag 104
BENTLEY DELIVERY CENTRE WA 6983

Phone (08) 9219 9512
Fax (08) 9334 0199

-----Original Message-----
From: Matthew Hamilton [mailto:Matthew.Hamilton@mtgibsoniron.com.au]
Sent: Wednesday, 25 May 2016 3:05 PM
To: Kuehs, Janine; Atkins, Ken
Cc: lara.jefferson@enperitus.com; Chant, Alanna; Troy Collie
Subject: RE: Darwinia masonii Translocation Proposal v4

Hi Ken and Janine,

Thanks for meeting with myself and Lara today. As discussed and as per the approved Translocation Proposal for Darwinia masonii, we are seeking endorsement from DPaW on the sites selected for upcoming scheduled translocations.

As per the map previously submitted, the translocation plots for Iron Hill / Iron Hill South plant material would include Sites 4, 6, 11, 12, 13, 14, 15, 16, 17. The sites at which Extension Hill material would be translocated to include Sites 1, 3, 18, 19.

For 2016, we intend to focus on 1, 4, 6, 14, 16 and 17. The other sites may be utilised next year or at a later date, although we will keep DPaW informed of progress in this regard.

Also, the translocation sites identified for Iron Hill / Iron Hill South may be the subject of future approval conditions from EPA in relation to the Iron Hill mining proposal.

Please let me know if you have any queries and as discussed we will keep you informed of potential seeding trials.

Cheers,

Matt Hamilton | Senior Environmental Officer Mount Gibson Iron Limited West Perth

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M: 0478 880 545

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-----Original Message-----
From: Kuehs, Janine [mailto:Janine.Kuehs@DPaW.wa.gov.au]
Sent: Monday, 23 May 2016 11:13 AM
To: Troy Collie <Troy.Collie@mtgibsoniron.com.au>
Cc: lara.jefferson@enperitus.com; Matthew Hamilton <Matthew.Hamilton@mtgibsoniron.com.au>; Atkins, Ken <Ken.Atkins@DPaW.wa.gov.au>; Chant, Alanna <Alanna.Chant@DPaW.wa.gov.au>
Subject: RE: Darwinia masonii Translocation Proposal v4

Hi Troy,

We would be able to meet with you on Wednesday 25th May at our Kensington office.

If you want to send through your short list ahead of time we can have a look before the meeting. I suggest the simplest way to present the information would be a map showing the proposed site locations with a table listing the source material proposed to be used for each site.

Regards
Janine

-----Original Message-----
From: Troy Collie [mailto:Troy.Collie@mtgibsoniron.com.au]
Sent: Thursday, 19 May 2016 1:21 PM
To: Kuehs, Janine; Page, Manda
Cc: lara.jefferson@enperitus.com; Matthew Hamilton; Atkins, Ken; Chant, Alanna
Subject: RE: Darwinia masonii Translocation Proposal v4

Hi Janine/Manda
Are we able to meet at your Perth offices early next week to discuss the plan to site? We now have a short list developed from a long list of sites. Anytime Monday 23 May afternoon through to Wednesday 25May next week would suit us.

Kind regards

**Appendix F:**
**Risk Assessment**

## 1. Context

In accordance with the Guidelines (EPA, 2014), MGM has considered reasonable risks to the delivery of each offset.

## 2. Risk Assessment Methodology

The risk management method engaged in this Plan is aligned with the AS/NZS ISO 31000: 2009 risk management standard, the Guidelines (EPA, 2014) and MGM internal policies, standards and risk procedures.

Firstly, sources of risk to the implementation of offsets listed in this Plan were identified. Secondly, an estimation of the likelihood of a risk event occurring and the consequence of the risk event to the implementation of the offset were estimated. Thirdly, the subsequent determination of a residual risk rating for each risk event was determined using a risk assessment matrix.

The likelihood and consequence parameters are provided in a risk assessment matrix (Table 1). Risk levels, priority and example of risk response actions are provided in Table 2.

**Table 1** Risk Matrix

| | **CONSEQUENCE** | | | | |
|---|---|---|---|---|---|
| **LIKELIHOOD** | **1. Insignificant** Minor delay (≤1 year) in implementing an offset | **2. Minor** Major delay (1-3 years) to implement an offset; Failure of a component of an offset | **3. Moderate** Repeated failure when implementing an offset | **4. Major** Offset cannot be implemented | **5. Catastrophic** Significant environmental harm due to implementing an offset |
| **5. Almost certain**: to happen in most circumstances | | | | | |
| **4. Likely:** To happen at some point, will occur in most circumstances | | | | | |
| **3. Possible:** Has happened in other situations; should occur at some time | | | | | |
| **2. Unlikely:** Not likely to happen | | | | | |
| **1.Rare:** Practicably impossible | | | | | |

**Table 2** Risk Levels, Priority level and Response Actions

| **Risk Levels** | **Priority** | **Risk response action** |
|---|---|---|

| | | |
|---|---|---|
| **Extreme** | 1 | Detailed research and planning required; determine whether or not to stop activity pending further investigation |
| **Significant/High** | 2 | Senior management attention; immediate corrective and preventative action required |
| **Moderate** | 3 | Management responsibility assigned; corrective and preventative action plan developed |
| **Low** | 4 | Manage by routine procedures; accept risk |

## 3. Sources of Risk

### Drought

Adequate rainfall is essential for the growth and establishment of seedlings or translocated plants in the field. Translocations and revegetation actions are likely to occur following rainfall conditions. However, plants are susceptible to adverse conditions, namely drought, during their first two years since planting (BGPA, 2010). Drought conditions have been shown to result in death of *Darwinia masonii* individuals that have been translocated (BGPA, 2010). This is also applicable to germinants and seedlings in rehabilitation areas and the translocation of *Lepidosperma gibsonii* plants.

Therefore, drought is a source of risk to the successful translocation of *Darwinia masonii* and *Lepidosperma gibsonii* plants, and the rehabilitation program. A response is to commence drought-susceptible actions after good rainfall and, potentially, with stakeholder agreement, delay certain actions during periods recognized as drought.

### Low rates of plant survival

Many of the proposed land management actions are prone to risks of poor seed germination and/or plant propagation. The effects of drought discussed above has a large bearing on plant survival and growth. Should in-field plant survival and growth not meet stipulated performance requirements established by component plans, then further work would be repeated in time in order that the success criteria are met. This may require further time for attaining outcomes at the site. For instance, for *D.masonii* translocation, as detailed in the Translocation Proposal, additional nursery stock would be generated at nursery and then used in the field.

### Weeds

Weeds have the potential to displace native vegetation by outcompeting seedlings/plants for soil nutrients and water. However, MGM has not experienced significant weed invasions since mining began in 2010. Regardless, weeds remain a risk that can be managed by monitoring and applying a rapid response regime i.e. identifying, removing and eradicating individual weeds prior to any significant seed set.

Weeds are a source of risk to the successful implementation of *Darwinia masonii* and *Lepidosperma gibsonii* translocations, and the rehabilitation program.

### Grazing pressure

Goats are well adapted to the semi-arid conditions of the Midwest region, and are often an economically viable commodity for pastoralists. Goat populations are often left untended until population sizes are sufficient and their worth makes them viable to send to market.

Goats cause significant damage to native vegetation as a result of heavy grazing. Goats are known to be present in areas to the south of the Mt Gibson Ranges and on the adjacent White Wells Station. However, destocking in the area has occurred and no significant grazing pressure has been observed on the Mt Gibson Ranges since mining began in 2010.

Should goat numbers increase it may result in increased grazing pressure, which is considered a source of risk to the successful implementation of *Lepidosperma gibsonii* translocations, and the rehabilitation program. Monitoring of goats and grazing pressure will occur to assess the level of risk.

## Fire

Fire ignition may occur naturally (i.e. lightning strike) or as the result of human activity. Fire is known to temporarily eliminate and/or change the composition of floristic communities. *Darwinia masonii* individuals are prone to fire and likely to result in death of adults or young plants. *Lepidosperma gibsonii* is less prone to the impacts of fire because it is a re-sprouter species and therefore capable of surviving the effects of a fire.

The presence of MGM mining operations will likely reduce the likelihood of an extensive or out of control fire occurring. The emergency response team can respond rapidly to a fire due to their proximity in the Mt Gibson Ranges and available fire-fighting resources (personnel and gear).

## Timing

MGM has started the propagation of *Darwinia masonii* cuttings taken from plants occurring within the Iron Hill Development Envelope. These cuttings are currently established and held at nursery. However, this species is not conducive to plants being maintained in pots under nursery conditions for long periods of time. Each year, a number of specimens will not survive and thus the total number of genotypes diminishes with time, unless they are re-cut and translocated.

A Translocation Proposal for *Darwinia masonii* has been submitted to and approved by Parks & Wildlife. A Translocation Proposal for *Lepidosperma gibsonii* has been submitted to Parks & Wildlife approved by Parks & Wildlife. The approval of the Translocation Proposals allows the offsets for the Iron Hill project to be implemented. The Guidelines (WA Government 2014) describes the advantages of and promotes using early offsets. However, a proactive approach to the early implementation of offsets poses a risk that the agreement of the offsets package will not occur in time for the translocations to occur in this 2016 season. By mutual agreement, early commencement could be agreed with government stakeholders.

## Erosion

Poor site preparation can result in the potential of surface soils to erode within the rehabilitated areas and into the surrounding environment. This has been evident on waste landforms and exploration areas that exist on the slopes of hills in other regional sites. Given that rehabilitation of historic exploration tracks and pads within the PEC areas of the Mt Gibson Ranges are on the slopes of the hills then there is a risk of erosion if the site is not prepared properly i.e. contours, placement of rock and gravel material.

## Research not conducted to plan

Numerous, small sources of risk can result in research not conducted to plan, including:

- Equipment failure;
- Human mistakes in implementing a chosen methodology;
- Accuracy of methodology;
- Personnel bias when interpreting results;
- Personnel experience (eg. research undertaken by students); and
- Unpredictability of analysis findings resulting in a change in recommended direction of research program.

The investigative nature of research often results in questions being raised, especially if findings are equivocal. Therefore flexibility is required and specific hypotheses established in order to also ensure a level of structure and outcomes based information. Sufficient information is required to ensure the methodology can be replicated and raw data provided for peer review and future statistical analysis.

Collaboration often supports open and productive projects, as various parties contribute to broad robust program outcomes. A mitigative mechanism would be to ensure that adequate supervision, peer support and value-adding opportunities maximize investment in work of this nature. Universities through CRC memberships and/or ARC Industry programs typify the execution and delivery entity. Because of its direct relevance to this offset program, and its related technical work outputs, MGM has registered its interest with the ARC-funded *Transformation Training Centre on Mining Restoration* (homed in WA where the administrative organisation is Curtin University of Technology).

## 4. Risk Assessment

A risk assessment was undertaken for each source of risk using likelihood (L) of the hazard and consequence (C) of the event happening taking into consideration current management actions in place. The likelihood and consequence matrix was used to determine the inherent risk level (Table 3).

**Table 3** Risk assessment to determine the inherent risk level.

| ID # | Risk Source | Hazard | Management | L | C | Inherent Risk Level |
|---|---|---|---|---|---|---|
| **1** | Drought | Offset D1: Death of translocated *Darwinia masonii* plants due to drought conditions | Translocation Proposal includes supplementary watering regime for first two years; proven methodology tested in 10 year translocation trial | 3 | 4 | High |
| **2** | Drought | Offset L1: Death of translocated *Lepidosperma gibsonii* plants due to drought conditions. | Translocation Proposal includes supplementary watering regime for first two years | 3 | 4 | High |
| **3** | Weeds | Offset D1 and L1: Weeds establish within translocation and rehabilitation areas reducing survival and establishment of native species. | Weed monitoring and control program currently being implemented | 2 | 1 | Low |
| **4** | Grazing pressure | Offset L1: Increase in goat population results in grazing pressures reducing survival and establishment of native species. | Grazing monitoring and control program implemented previously | 2 | 1 | Low |
| **5** | Fire ignition | Offset D1 and L1: Fire eradicates native vegetation in translocation areas. | Emergency Response Team at the mine site, fire fighting training, fire procedures, species adapted to fire through germination response or resprouters therefore most prone in the short-medium term. | 3 | 2 | Moderate |
| **6** | Timing | Offset D1 and L1: Establishment of cuttings under nursery conditions prior to consultation and | Offsets Guidance Statement (EPA, 2014) promotes early implementation of offsets | 3 | 2 | Moderate |

| ID # | Risk Source | Hazard | Management | L | C | Inherent Risk Level |
|---|---|---|---|---|---|---|
| | | agreement on offsets resulting in delay of translocation and loss of plants under nursery conditions | | | | |
| **7** | Research not conducted to plan | Offset L2: Research proposal is not implemented or delivered as described. | As described. Collaborative university based industry programs; competent professionals whose progress is tracked by MGI personnel | 4 | 2 | Moderate |

## 5. Risk Mitigation

Inherent risk levels ranged from low to high. Where inherent risk is considered to be moderate or high, further mitigation has been considered to reduce the risk to acceptable levels (Table 4).

**Table 4** Risk assessment following mitigation to determine the residual risk level

| ID# | Inherent Risk Level | Mitigation Actions | L | C | Residual Risk Level |
|---|---|---|---|---|---|
| **1 and 2** | High | Monitoring of plant condition, irrigation program for supplementary watering when required, maintain clones of genotypes in nursery for 3 years. | 3 | 2 | Moderate |
| **1 and 2** | High | Maintain additional seed for contingency seeding and planting; irrigation if required during first 2 years. | 3 | 2 | Moderate |
| **5** | Moderate | Maintain additional genotypes of DRF in nursery over the short –medium term, maintain additional seed for rehabilitation. | 3 | 1 | Low |
| **6** | Moderate | Consult with Parks & Wildlife and EPA regarding timing and implications associated with maintaining plants in the nursery for another 12 months. | 2 | 2 | Low |
| **7** | Moderate | Adaptive management approach to research program; Expert peer reviews; Collaborative program framework; Detailed research proposal including hypotheses, research methodology, scientists/students and credentials; progress reports and quarterly meetings; contractual agreements regarding reporting, detail in methodology and provision of raw data; peer review | 3 | 1 | Low |

**Appendix G:**
**Background Information and Data for Translocation Sites**

# ***Darwinia masonii*** **Translocation Site – Plot 4 – Notes**

Map and Layout

The map and layout is shown by Figure 1 below.

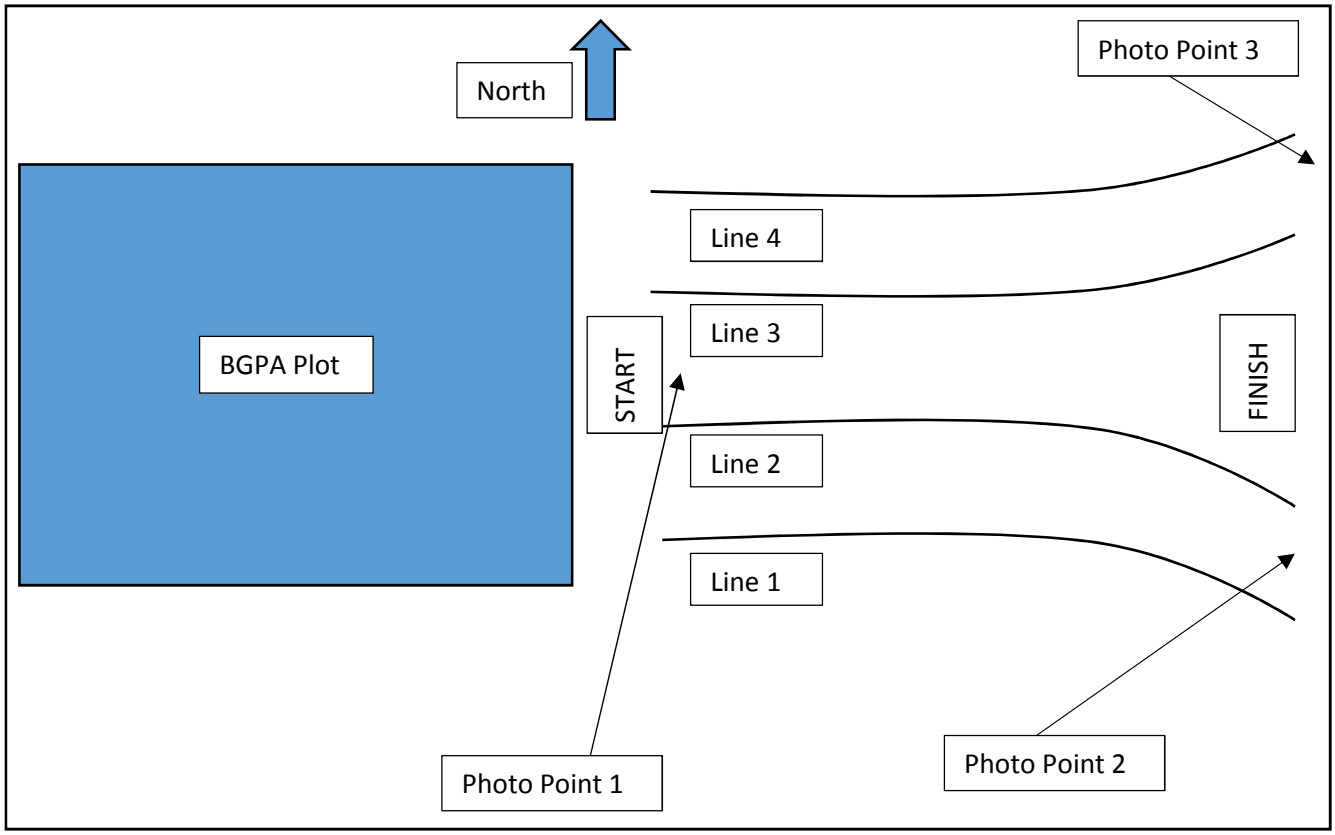



**Figure 1:** Map and layout of *Darwinia masonii* Translocation Plot 4.

Photo Monitoring Points

| No.# | Details | Initial Photo (13/7/2016) |
|---|---|---|
| 1 | West end facing East | |

| | | |
|---|---|---|
| 2 | South east end face west | |

| | | |
|---|---|---|
| 3 | North east end face west | |

**Methodology:**

History

The site was part of a previous trial conducted by BGPA and is adjacent to the BGPA plot which successfully applied irrigation. There are approximately 180 *Darwinia masonii* surviving and flowering within this plot after 10 years. The site was previously ripped approximately 9-10 years ago and there were four clear rip lines adjacent to the BGPA plot where irrigation lines have now been placed.

Date of Planting

Planting commenced on the 12th of July 2016 and was finished on the 13th of July 2016.

Method of planting

Holes were dug using hand trowels and a crowbar approximately 20cm deep or enough so the top soil of the seedling was covered. Before placing the plant in the hole a fertilizer tablet was placed in the hole (Typhoon native slow release tablet) and covered with soil so it was not directly touching the plant roots. The hole was filled in with surrounding soil and a small well shaped for the purpose of holding water above the plant. The plants were then watered in with approximately 500ml to 1 litre of water. This allowed the surrounding soil to mould together and bind around the plant.

Tagging of plants

On the irrigation line each plant was labelled with a metal ID to identify the genotype of the plant. A bamboo stake was also placed at each plant to allow for easy spotting of each plants location. A list of all plant numbers and their genotype is within Appendix 1.

Substrate / Ground

The ground varied with the southerly lines (Line 1 and Line 2) being in more rocky and harder ground which was harder to dig. The northerly lines (Line 3 and Line 4) were in softer ground, though it was clear there was still gravel and rocks which had been upturned by previous ripping. The ground of lines 3 and 4 was easier to dig due to higher soil content and less rocky material.

The substrate was predominantly soil type 2 (lines 1 and 2) and 3 (lines 3 and 4), as per the key below.

| Soil Type | Description |
|---|---|
| 1 | Sandy duplex soils of moderate to high depth (e.g. sandy plains), red in colour |
| 2 | Sandy loams of shallow to moderate depth with sparse to moderate rock outcroppings (e.g. lower and mid slopes of BIF), red in colour |
| 3 | Sandy loams of shallow depth with extensive rock outcroppings and scattered stones (e.g. mid and upper slopes of BIF), red in colour |
| 4 | Extensive Banded Ironstone Formation outcroppings of limited depth (BIF crests) |

Rainfall

At the time of planting the ground was moist / damp due to recent rainfall which did also make digging holes easier. The table below shows rainfall from June to October 2016.

Mulch / Existing Vegetation

There was some mulch on the ground but it was not widely covering the site. The site had been used by BGPA for a trial previously on *Darwinia masonii*, although this plot was not irrigated by BGPA as per the BGPA plot directly adjacent. Since this time there was no remaining *Darwinia masonii* and other species had begun recolonizing the disturbed ground. This did not limit access but it did limit the layout of the irrigation lines. See Map Layout and photos above.

Origin of plants

The plants were grown in nursery by Ben Croxford (Manager) at the Nuts about Natives Nursery from cuttings collected from Iron Hill during spring 2015.

Expertise of planters

Ben Croxford assisted with the planting on 12 and 13 July and provided guidance on the technique. Others involved were Matt Hamilton (Snr Environmental Officer MGM) and Phil Readhead (Snr Environmental Officer MGM).

Condition of plants

The juvenile plants appeared to be in good condition with green healthy leaves. Heights were recorded and ranged from approximately 9cm to 30cm. The soil contained within the pots was moist at the time of planting.

According to the key below, the seedling health was within Type 1 and 2.

| **Seedling Health Type** | **Description** |
|---|---|
| 1 | Excellent (e.g. multi-stemmed, new growth, vivid colour, >20cm height, healthy root mass which is not root-bound) |
| 2 | Moderate (e.g. single and multi-stemmed, a high proportion of new growth, atypical colour, 10-20cm in height, healthy root mass, slightly root bound) |
| 3 | Poor (e.g. single stemmed, minimal new growth, lighter in colour, <10cm height, mostly root bound, evidence of senescence) |

**Appendix 1 - Line Sequence Per Genotype**

| LINE1 | | LINE 2 | | LINE 3 | | LINE 4 | |
|---|---|---|---|---|---|---|---|
| PLANT # | GENOTYPE | PLANT # | GENOTYPE | PLANT # | GENOTYPE | PLANT # | GENOTYPE |
| 1 | INF2 | 43 | INF73 | 89 | IND39A | 129 | IND39A |
| 2 | INF5 | 44 | INF61 | 90 | IND39A | 130 | IND39A |
| 3 | INF2 | 45 | INF59 | 91 | IND39A | 131 | IND39A |
| 4 | INF10 | 46 | INF203 | 92 | IND39B | 132 | IND38 |
| 5 | INF12 | 47 | INF193 | 93 | IND39B | 133 | IND39B |
| 6 | INF15 | 48 | INF159 | 94 | IND33 | 134 | IND33 |
| 7 | INF26 | 49 | INF141 | 95 | IND33 | 135 | IND33 |
| 8 | INF18 | 50 | INF154 | 96 | IND30 | 136 | IND33 |
| 9 | INF19 | 51 | INF138 | 97 | IND30 | 137 | IND33 |
| 10 | INF22 | 52 | INF140 | 98 | IND18 | 138 | IND22 |
| 11 | INF22 | 53 | INF125 | 99 | IND17 | 139 | IND17 |
| 12 | INF2 | 54 | INF123 | 100 | IND17 | 140 | IND17 |
| 13 | INF4 | 55 | INF123 | 101 | IND17 | 141 | IND17 |
| 14 | INF26 | 56 | INF118 | 102 | IND16 | 142 | IND14 |
| 15 | INF37 | 57 | INF120 | 103 | IND16 | 143 | IND11 |
| 16 | INF38 | 58 | INF115 | 104 | IND6 | 144 | IND3 |
| 17 | INF37 | 59 | INF115 | 105 | IND3 | 145 | IND6 |
| 18 | INF44 | 60 | INF114 | 106 | IND1 | 146 | IND3 |
| 19 | INF44 | 61 | INF109 | 107 | IND1 | 147 | IND1 |
| 20 | INF44 | 62 | INF114 | 108 | IND3 | 148 | IND1 |
| 21 | INF46 | 63 | INF114 | 109 | IND69 | 149 | IND67 |
| 22 | INF46 | 64 | INF109 | 110 | IND69 | 150 | IND67 |
| 23 | INF47 | 65 | INF109 | 111 | IND69 | 151 | IND76 |
| 24 | INF47 | 66 | INF76 | 112 | IND68 | 152 | IND69 |
| 25 | INF47 | 67 | INF108 | 113 | IND68 | 153 | IND67 |
| 26 | INF48 | 68 | INF91 | 114 | IND69 | 154 | IND72 |
| 27 | INF59 | 69 | INF107 | 115 | IND66 | 155 | IND72 |
| 28 | INF61 | 70 | INF76 | 116 | IND70 | 156 | IND71 |
| 29 | INF59 | 71 | INF108 | 117 | IND74 | 157 | IND74 |
| 30 | INF50 | 72 | INF77 | 118 | IND73 | 158 | IND67 |
| 31 | INF59 | 73 | INF107 | 119 | IND73 | 159 | IND80 |
| 32 | INF61 | 74 | INF104 | 120 | IND66 | 160 | IND79 |
| 33 | INF61 | 75 | INF79 | 121 | IND69 | 161 | IND88 |
| 34 | INF62 | 76 | INF77 | 122 | IND76 | 162 | IND70 |
| 35 | INF62 | 77 | INF106 | 123 | IND77 | 163 | IND72 |
| 36 | INF70 | 78 | INF106 | 124 | IND81 | 164 | IND76 |
| 37 | INF61 | 79 | INF104 | 125 | IND86 | 165 | IND90 |

| Line 1 | | Line 2 | | Line 3 | | Line 4 | |
|---|---|---|---|---|---|---|---|
| **PLANT #** | **GENOTYPE** | **PLANT #** | **GENOTYPE** | **PLANT #** | **GENOTYPE** | **PLANT #** | **GENOTYPE** |
| 38 | INB141 | 80 | INF108 | 126 | IND96 | 166 | IND83 |
| 39 | INB141 | 81 | INF107 | 127 | IND96 | 167 | IND83 |
| 40 | INB130 | 82 | INF107 | 128 | INB133 | 168 | IND92 |
| 41 | INB130 | 83 | INF109 | | | 169 | IND94 |
| 42 | INB132 | 84 | INF108 | | | | |
| | | 85 | INF108 | | | | |
| | | 86 | INB135 | | | | |
| | | 87 | INB133 | | | | |
| | | 88 | INB139 | | | | |

**Appendix 2 – Rainfall**

| Date | Period End | Jun-16 | Jul-16 | Aug-16 | Sep-16 | Oct-16 |
|---|---|---|---|---|---|---|
| 1 | 6:00 | 0 | 0 | 0 | 0.2 | 0.8 |
| 1 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 2 | 6:00 | 0 | 0 | 0 | 0 | 0.2 |
| 2 | 18:00 | 0 | 0.4 | 0 | 0 | 0 |
| 3 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 3 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 4 | 6:00 | 0 | 0 | 2.4 | 0 | 0 |
| 4 | 18:00 | 7 | 0 | 2.6 | 0 | 0 |
| 5 | 6:00 | 0 | 0 | 0.2 | 0 | 0 |
| 5 | 18:00 | 0.2 | 0 | 0 | 0 | 0 |
| 6 | 6:00 | 0 | 0 | 0.2 | 0 | 0 |
| 6 | 18:00 | 0.2 | 0 | 0.4 | 0 | 0 |
| 7 | 6:00 | 5.4 | 0 | 1.2 | 0 | 0 |
| 7 | 18:00 | 4.2 | 0 | 0.2 | 2.2 | 0 |
| 8 | 6:00 | 0.2 | 0 | 0 | 0 | 0 |
| 8 | 18:00 | 0 | 16.6 | 3.4 | 0 | 4.4 |
| 9 | 6:00 | 0 | 16.4 | 0.2 | 0 | 0.4 |
| 9 | 18:00 | 0.2 | 0.4 | 0 | 0 | 0 |
| 10 | 6:00 | 0 | 0.2 | 0 | 0 | 0 |
| 10 | 18:00 | 0 | 2 | 0.2 | 0 | 0 |
| 11 | 6:00 | 0 | 0.2 | 0 | 0 | 0 |
| 11 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 12 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 12 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 13 | 6:00 | 7 | 0 | 0 | 0 | 0 |
| 13 | 18:00 | 2 | 0 | 0 | 0 | 0 |
| 14 | 6:00 | 0.4 | 0 | 0 | 0 | 0 |
| 14 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 15 | 6:00 | 0.2 | 0 | 0 | 0 | 0.2 |
| 15 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 16 | 6:00 | 0 | 0 | 0 | 0 | 0 |

| Date | Period End | Jun-16 | Jul-16 | Aug-16 | Sep-16 | Oct-16 |
|---|---|---|---|---|---|---|
| 16 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 17 | 6:00 | 0.2 | 4.6 | 0 | 0 | 0 |
| 17 | 18:00 | 0 | 7.2 | 5.8 | 0 | 0 |
| 18 | 6:00 | 0 | 0.8 | 2.2 | 0 | 0 |
| 18 | 18:00 | 0 | 0.4 | 0.2 | 0 | 0 |
| 19 | 6:00 | 0 | 0 | 0 | 4 | 0 |
| 19 | 18:00 | 0 | 0.2 | 0 | 0 | 0 |
| 20 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 20 | 18:00 | 5.2 | 0.2 | 0 | 0 | 0.2 |
| 21 | 6:00 | 5.2 | 0 | 0 | 0 | 0 |
| 21 | 18:00 | 0 | 0.8 | 0 | 0 | 0 |
| 22 | 6:00 | 0.2 | 0.4 | 1.8 | 0 | 0 |
| 22 | 18:00 | 0 | 0 | 0.2 | 0 | 0 |
| 23 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 23 | 18:00 | 0.2 | 0 | 0 | 0.4 | 0 |
| 24 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 24 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 25 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 25 | 18:00 | 0.8 | 0.2 | 0 | 0 | 0 |
| 26 | 6:00 | 0.2 | 0 | 0 | 0 | 0 |
| 26 | 18:00 | 0.2 | 0 | 0 | 0 | 0 |
| 27 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 27 | 18:00 | 0 | 0 | 14.6 | 0 | 0 |
| 28 | 6:00 | 0 | 0 | 0.6 | 0 | 0 |
| 28 | 18:00 | 0 | 0 | 3.4 | 0 | 0 |
| 29 | 6:00 | 0.4 | 0.4 | 0 | 0 | 0 |
| 29 | 18:00 | 1.8 | 0 | 0 | 0 | 0 |
| 30 | 6:00 | 0.2 | 0 | 0 | 0 | 0 |
| 30 | 18:00 | 0 | 0.2 | 0 | 0 | 0 |
| 31 | 6:00 |  | 0 | 0 |  | 0 |
| 31 | 18:00 |  | 0.2 | 4.2 |  | 0 |
| **Total** | | **41.6** | **51.8** | **44** | **6.8** | **6.2** |

# *Darwinia masonii* Translocation Site – Plot 14 – Notes

Map and Layout

The map and layout is shown by Figure 1 below.

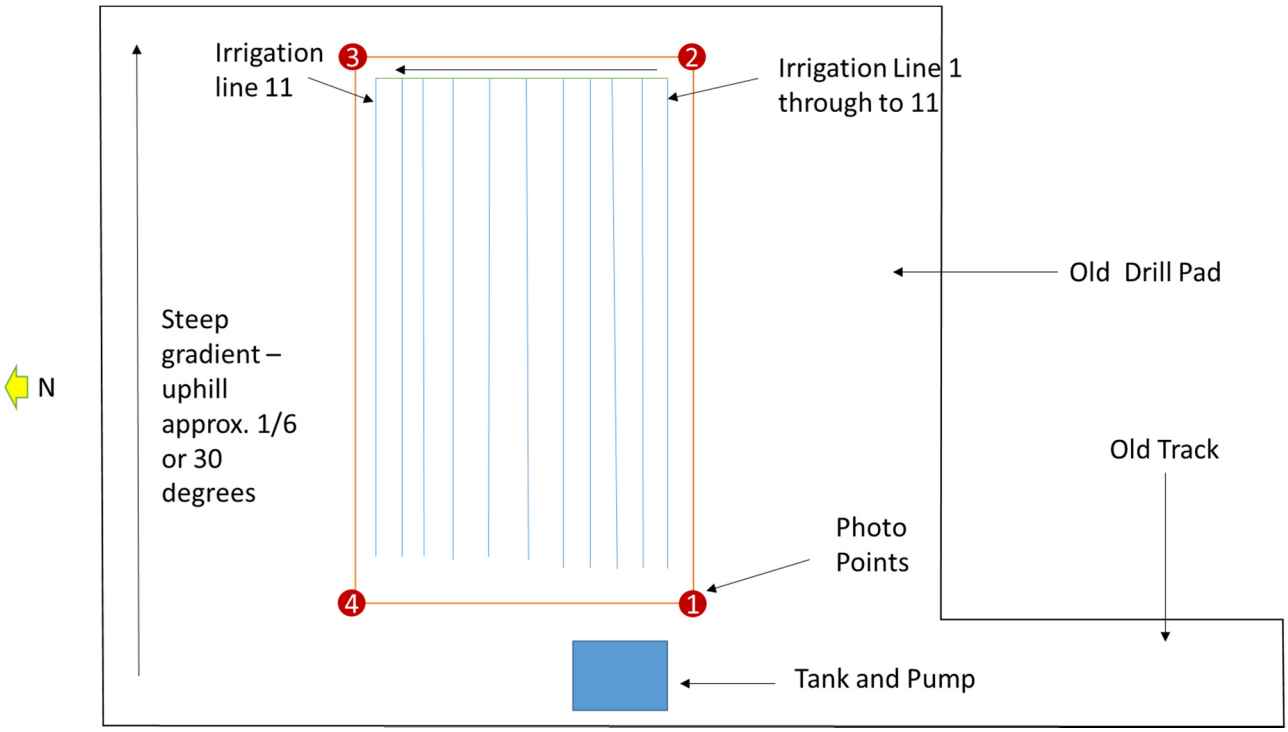
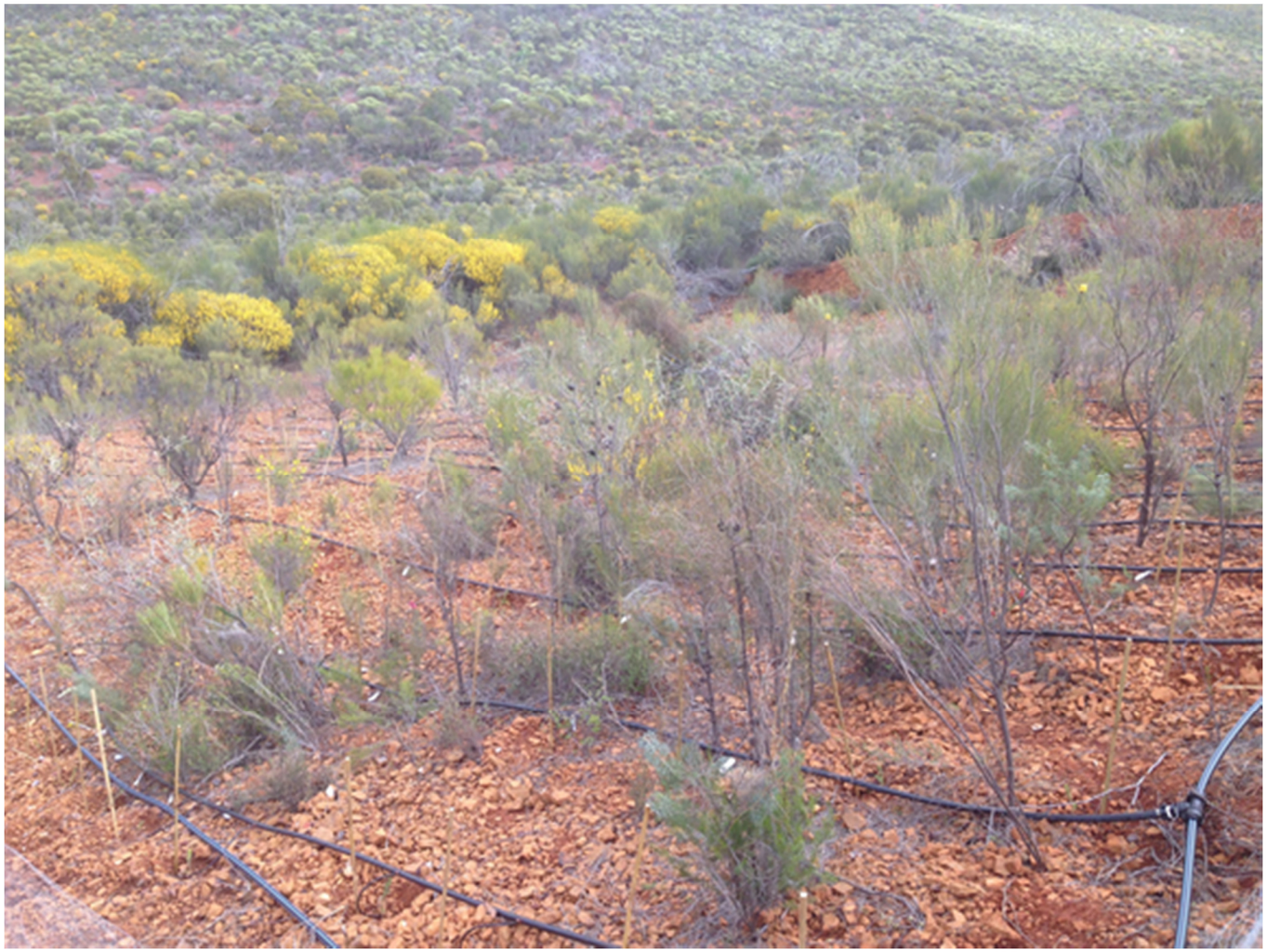



**Figure 1:** Map and layout of *Darwinia masonii* translocation plot 14.

Photo Monitoring Points

| No.# | Details | Initial Photo (13/7/2016) |
|---|---|---|
| 1 | Facing North East | |

| | | |
|---|---|---|
| 2 | Facing North West |  |
| 3 | Facing South West | |

| | | |
|---|---|---|
| | | |

| | | |
|---|---|---|
| | Facing South East | |

**Methodology:**

History

The site is a former drill pad utilised for exploration prior to MGM and Asia Iron. As seen by the photo below, there has been recolonization of pioneering species since disturbance. Those species have been retained with irrigation lines installed surrounding them. The steep gradient (approx. 30 degrees) running from the low point in the west to the high point in the east, is also evident.

Date of Planting

The site was initially planted on the 1st and 2nd of August 2016 with juvenile *Darwinia masonii* individuals.

Method of planting

Holes were dug with crowbars as the ground was hard to penetrate in some areas. Before placing the plant in the hole a fertilizer tablet was placed in the hole (Typhoon native slow release tablet) and covered with soil so it was not directly touching the plant roots. The hole was filled in with surrounding soil and a small well shaped for the purpose of holding water above the plant. The plants were not watered in as it was considered due to recent rains the ground was already quite moist and due to the rocky nature of the substrate watering in did not appear to have an effect on the substrate binding with and around the soil of the seedling.

Tagging of plants

On the irrigation line each plant was labelled with a metal ID to identify the genotype of the plant. A bamboo stake was also placed at each plant to allow for easy spotting of each plants location. A list of all plant numbers and their genotype is within Appendix 1.

Substrate / Ground

The site was not ripped prior to planting and the digging of holes. This was due to the steepness of the terrain and also to retain the existing vegetation which had colonized the previously disturbed area. The gradient of the terrain was very steep as detailed by the History section above. The soil varied across the site with regard to clay/gravel/rock content. Some parts were rocky and could not be dug with tools available and to some degree there were large boulders within the ground which prohibited planting. Other holes with a higher clay content could be dug relatively easily and other holes varied between these two extremes. Some holes had a very low content of fill material to replace the hole with once the plant was placed in the ground.

The substrate was predominantly soil type 3, as per the key below.

| Soil Type | Description |
|---|---|
| 1 | Sandy duplex soils of moderate to high depth (e.g. sandy plains), red in colour |
| 2 | Sandy loams of shallow to moderate depth with sparse to moderate rock outcroppings (e.g. lower and mid slopes of BIF), red in colour |
| 3 | Sandy loams of shallow depth with extensive rock outcroppings and scattered stones (e.g. mid and upper slopes of BIF), red in colour |
| 4 | Extensive Banded Ironstone Formation outcroppings of limited depth (BIF crests) |

Rainfall

At the time of planting the ground was moist / damp due to recent rainfall. Appendix 2 shows the rainfall from June to October 2016.

Mulch / Existing Vegetation

As detailed by History above, there was quite a lot of existing vegetation and there was some mulch on the ground, however this was not widespread due to the lower density of vegetation compared to the surrounding environment. Prior to placement of irrigation lines and planting, dead trees were removed by hand to increase the space available for juvenile plants. It is expected that those dead trees removed were not long lived species and acted as early colonisers.

Origin of plants

The plants were grown in nursery by Ben Croxford (Manager) at the Nuts about Natives Nursery from cuttings collected from Iron Hill during spring 2015.

Expertise of planters

Planters included Matt Hamilton (Senior Environmental Advisor MGM), Andrew Vear (Senior Field Project Lead Greening Australia) and Joseph Meadham (Casual Field Assistant Greening Australia). Both Joseph and Andrew had undertaken similar works for Greening Australia previously.

Condition of plants

The juvenile plants appeared to be in good condition with green healthy leaves. Heights ranged from approximately 4cm to 28cm. The soil contained within the pots was moist at the time of planting.

According to the key below, the seedling health was within Type 1 and 2.

| Seedling Health Type | Description |
|---|---|
| 1 | Excellent (e.g. multi-stemmed, new growth, vivid colour, >20cm height, healthy root mass which is not root-bound) |
| 2 | Moderate (e.g. single and multi-stemmed, a high proportion of new growth, atypical colour, 10-20cm in height, healthy root mass, slightly root bound) |
| 3 | Poor (e.g. single stemmed, minimal new growth, lighter in colour, <10cm height, mostly root bound, evidence of senescence) |

**Appendix 1 - Line Sequence Per Genotype**

| LINE1 | | LINE2 | | LINE3 | | LINE4 | |
|---|---|---|---|---|---|---|---|
| PLANT # | GENOTYPE | PLANT # | GENOTYPE | PLANT # | GENOTYPE | PLANT # | GENOTYPE |
| 1 | ISD44 | 33 | INF2 | 63 | ISD44 | 98 | ISB60 |
| 2 | ISD44 | 34 | INF5 | 64 | ISD6 | 99 | ISB60 |
| 3 | ISD44 | 35 | INF44 | 65 | ISB41 | 100 | ISD40 |
| 4 | ISD44 | 36 | INF2 | 66 | ISD8 | 101 | ISD3 |
| 5 | ISD44 | 37 | INF2 | 67 | ISD3 | 102 | ISD38 |
| 6 | ISD47 | 38 | INF22 | 68 | ISD44 | 103 | ISD42 |
| 7 | ISD53 | 39 | INF19 | 69 | ISD40 | 104 | ISD44 |
| 8 | ISD47 | 40 | INF44 | 70 | ISD44 | 105 | ISD19 |
| 9 | ISD47 | 41 | INF47 | 71 | ISD44 | 106 | ISD35 |
| 10 | ISD47 | 42 | INF61 | 72 | ISD4 | 107 | ISD7 |
| 11 | ISD53 | 43 | INF47 | 73 | ISD5 | 108 | ISD3 |
| 12 | ISD53 | 44 | INF61 | 74 | ISD5 | 109 | ISD3 |
| 13 | ISD53 | 45 | INF26 | 75 | ISD3 | 110 | ISD4 |
| 14 | ISD57 | 46 | INF59 | 76 | ISB4 | 111 | ISB3 |
| 15 | ISD68 | 47 | INF22 | 77 | ISB3 | 112 | ISB4 |
| 16 | ISD68 | 48 | INF19 | 78 | ISB5 | 113 | ISB4 |
| 17 | ISD57 | 49 | INF61 | 79 | ISB4 | 114 | ISB9 |
| 18 | IND96 | 50 | INF61 | 80 | ISB5 | 115 | ISB9 |
| 19 | IND90 | 51 | INF44 | 81 | ISB9 | 116 | ISB37 |
| 20 | IND94 | 52 | INF31 | 82 | ISB29 | 117 | ISB37 |
| 21 | IND57 | 53 | INF37 | 83 | ISB27 | 118 | ISB23 |
| 22 | IND88 | 54 | INF61 | 84 | ISB10 | 119 | ISB44 |
| 23 | ISD68 | 55 | INF44 | 85 | ISB23 | 120 | ISB5 |
| 24 | ISD64 | 56 | INF50 | 86 | ISB23 | 121 | ISB23 |
| 25 | ISD68 | 57 | INF61 | 87 | ISB23 | 122 | ISB16 |
| 26 | INF62 | 58 | INF61 | 88 | ISB37 | 123 | ISD5 |
| 27 | INF67 | 59 | INF61 | 89 | ISD5 | 124 | ISD25 |
| 28 | INF70 | 60 | INF59 | 90 | ISD12 | 125 | ISD10 |
| 29 | INF26 | 61 | INF59 | 91 | ISD3 | 126 | ISD25 |
| 30 | INF62 | 62 | INF47 | 92 | ISD3 | 127 | ISD25 |
| 31 | NO TAG | | | 93 | ISD38 | 128 | ISD11 |
| 32 | INF62 | | | 94 | NO TAG | 129 | ISD6 |
| | | | | 95 | INF46 | 130 | ISD43 |
| | | | | 96 | INF46 | 131 | ISD44 |
| | | | | 97 | INF26 | 132 | ISD44 |
| | | | | | | 133 | ISD44 |
| | | | | | | 134 | USD43 |

| LINE5 | | LINE6 | | LINE7 | | LINE8 | |
|---|---|---|---|---|---|---|---|
| PLANT # | GENOTYPE | PLANT # | GENOTYPE | PLANT # | GENOTYPE | PLANT # | GENOTYPE |
| | | | | 135 | IND40 | 143 | ISB3 |
| | | | | 136 | IND40 | 144 | ISB37 |
| | | | | 137 | IND39 | 145 | ISB10 |
| | | | | 138 | IND17 | 146 | ISB9 |
| | | | | 139 | IND17 | 147 | ISB37 |
| | | | | 140 | IND17 | 148 | ISB8 |
| | | | | 141 | IND17 | 149 | ISB41 |
| | | | | 142 | IND17 | 150 | ISB43 |
| | | | | | | 151 | ISB3 |
| | | | | | | 152 | ISB62 |
| | | | | | | 153 | ISC3 |
| | | | | | | 154 | ISB62 |
| | | | | | | 155 | ISB61 |
| | | | | | | 156 | ISC3 |
| | | | | | | 157 | ISB61 |
| | | | | | | 158 | IND17 |
| | | | | | | 159 | IND33 |
| | | | | | | 160 | IND17 |
| | | | | | | 161 | IND398 |
| | | | | | | 162 | IND33 |
| | | | | | | 163 | IND22 |
| | | | | | | 164 | IND33 |
| | | | | | | 165 | INB17 |
| | | | | | | 166 | INB17 |
| | | | | | | 167 | IND17 |
| | | | | | | 168 | IND17 |
| | | | | | | 169 | IND17 |

| LINE9 | | LINE10 | | LINE11 | |
|---|---|---|---|---|---|
| **PLANT #** | **GENOTYPE** | **PLANT #** | **GENOTYPE** | **PLANT #** | **GENOTYPE** |
| 170 | ISD3 | 191 | ISD3 | 218 | ISC101 |
| 171 | ISD3 | 192 | ISD3 | 219 | ISC80 |
| 172 | ISB9 | 193 | ISD3 | 220 | ISC101 |
| 173 | ISB10 | 194 | ISC80 | 221 | ISC101 |
| 174 | ISC3 | 195 | ISC12 | 222 | ISD3 |
| 175 | ISC12 | 196 | ISC12 | 223 | ISC41 |
| 176 | ISC3 | 197 | ISC12 | 224 | ISC80 |
| 177 | ISC11 | 198 | ISC22 | 225 | ISC94 |
| 178 | ISC23 | 199 | ISC36 | | |
| 179 | ISC36 | 200 | ISC89 | | |
| 180 | ISC79 | 201 | ISC36 | | |
| 181 | IND33 | 202 | ISC89 | | |
| 182 | IND33 | 203 | ISC36 | | |
| 183 | IND33 | 204 | ISC89 | | |
| 184 | IND39 | 205 | ISC87 | | |
| 185 | IND39 | 206 | ISC99 | | |
| 186 | IND17 | 207 | IND17 | | |
| 187 | IND17 | 208 | IND39 | | |
| 188 | IND17 | 209 | NO TAG | | |
| 189 | IND17 | 210 | IND33 | | |
| 190 | IND17 | 211 | IND16 | | |
| | | 212 | IND39 | | |
| | | 213 | IND33 | | |
| | | 214 | IND22 | | |
| | | 215 | IND17 | | |
| | | 216 | IND30 | | |
| | | 217 | ISC36 | | |

**Appendix 2 – Rainfall**

| Date | Period End | Jun-16 | Jul-16 | Aug-16 | Sep-16 | Oct-16 |
|---|---|---|---|---|---|---|
| 1 | 6:00 | 0 | 0 | 0 | 0.2 | 0.8 |
| 1 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 2 | 6:00 | 0 | 0 | 0 | 0 | 0.2 |
| 2 | 18:00 | 0 | 0.4 | 0 | 0 | 0 |
| 3 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 3 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 4 | 6:00 | 0 | 0 | 2.4 | 0 | 0 |
| 4 | 18:00 | 7 | 0 | 2.6 | 0 | 0 |
| 5 | 6:00 | 0 | 0 | 0.2 | 0 | 0 |
| 5 | 18:00 | 0.2 | 0 | 0 | 0 | 0 |
| 6 | 6:00 | 0 | 0 | 0.2 | 0 | 0 |
| 6 | 18:00 | 0.2 | 0 | 0.4 | 0 | 0 |
| 7 | 6:00 | 5.4 | 0 | 1.2 | 0 | 0 |
| 7 | 18:00 | 4.2 | 0 | 0.2 | 2.2 | 0 |
| 8 | 6:00 | 0.2 | 0 | 0 | 0 | 0 |
| 8 | 18:00 | 0 | 16.6 | 3.4 | 0 | 4.4 |
| 9 | 6:00 | 0 | 16.4 | 0.2 | 0 | 0.4 |
| 9 | 18:00 | 0.2 | 0.4 | 0 | 0 | 0 |
| 10 | 6:00 | 0 | 0.2 | 0 | 0 | 0 |
| 10 | 18:00 | 0 | 2 | 0.2 | 0 | 0 |
| 11 | 6:00 | 0 | 0.2 | 0 | 0 | 0 |
| 11 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 12 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 12 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 13 | 6:00 | 7 | 0 | 0 | 0 | 0 |
| 13 | 18:00 | 2 | 0 | 0 | 0 | 0 |
| 14 | 6:00 | 0.4 | 0 | 0 | 0 | 0 |
| 14 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 15 | 6:00 | 0.2 | 0 | 0 | 0 | 0.2 |
| 15 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 16 | 6:00 | 0 | 0 | 0 | 0 | 0 |

| Date | Period End | Jun-16 | Jul-16 | Aug-16 | Sep-16 | Oct-16 |
|---|---|---|---|---|---|---|
| 16 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 17 | 6:00 | 0.2 | 4.6 | 0 | 0 | 0 |
| 17 | 18:00 | 0 | 7.2 | 5.8 | 0 | 0 |
| 18 | 6:00 | 0 | 0.8 | 2.2 | 0 | 0 |
| 18 | 18:00 | 0 | 0.4 | 0.2 | 0 | 0 |
| 19 | 6:00 | 0 | 0 | 0 | 4 | 0 |
| 19 | 18:00 | 0 | 0.2 | 0 | 0 | 0 |
| 20 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 20 | 18:00 | 5.2 | 0.2 | 0 | 0 | 0.2 |
| 21 | 6:00 | 5.2 | 0 | 0 | 0 | 0 |
| 21 | 18:00 | 0 | 0.8 | 0 | 0 | 0 |
| 22 | 6:00 | 0.2 | 0.4 | 1.8 | 0 | 0 |
| 22 | 18:00 | 0 | 0 | 0.2 | 0 | 0 |
| 23 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 23 | 18:00 | 0.2 | 0 | 0 | 0.4 | 0 |
| 24 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 24 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 25 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 25 | 18:00 | 0.8 | 0.2 | 0 | 0 | 0 |
| 26 | 6:00 | 0.2 | 0 | 0 | 0 | 0 |
| 26 | 18:00 | 0.2 | 0 | 0 | 0 | 0 |
| 27 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 27 | 18:00 | 0 | 0 | 14.6 | 0 | 0 |
| 28 | 6:00 | 0 | 0 | 0.6 | 0 | 0 |
| 28 | 18:00 | 0 | 0 | 3.4 | 0 | 0 |
| 29 | 6:00 | 0.4 | 0.4 | 0 | 0 | 0 |
| 29 | 18:00 | 1.8 | 0 | 0 | 0 | 0 |
| 30 | 6:00 | 0.2 | 0 | 0 | 0 | 0 |
| 30 | 18:00 | 0 | 0.2 | 0 | 0 | 0 |
| 31 | 6:00 |  | 0 | 0 |  | 0 |
| 31 | 18:00 |  | 0.2 | 4.2 |  | 0 |
| **Total** | | **41.6** | **51.8** | **44** | **6.8** | **6.2** |

# *Darwinia masonii* Translocation Site – Plot 16 – Notes

Map and Layout

The map and layout is shown by Figure 1.

History

Site was a previous exploration track prior to MGM and Asia Iron. Over the years the upper surface had become hardened due to the clay content, use of vehicles and lack of vegetation regrowth.

Date of Planting

4th of August 2016.

Method of planting

Site was initially ripped using a small three tonne excavator. As there was no existing regrowth, no vegetation was disturbed during ripping. Holes were dug mostly using picks and hoes. Before placing the plant in the hole a fertilizer tablet was placed in the hole (Typhoon native slow release tablet) and covered with soil so it was not directly touching the plant roots. The hole was filled in with surrounding soil and a small well shaped for the purpose of holding water above the plant. Due to rainfall just prior to planting and after planting, the ground was already moist/wet and therefore watering in of the plants was considered unnecessary, as opposed to Plot 4 where all plants were watered in.

Tagging of plants

On the irrigation line each plant was labelled with a metal ID to identify the genotype of the plant. A bamboo stake was also placed at each plant to allow for easy spotting of each plants location. Appendix lists all plant numbers and their genotypes.

Substrate / Ground

Ground was hard prior to ripping and difficult to dig. Following ripping, holes were able to be dug easily therefore crowbars were not necessary and mattocks were used instead. The substrate varied in a similar way to that of Plot 14, however the clay content was generally greater across the entire site.

The substrate was predominantly soil type 2 as per the key below.

| Soil Type | Description |
|---|---|
| 1 | Sandy duplex soils of moderate to high depth (e.g. sandy plains), red in colour |
| 2 | Sandy loams of shallow to moderate depth with sparse to moderate rock outcroppings (e.g. lower and mid slopes of BIF), red in colour |
| 3 | Sandy loams of shallow depth with extensive rock outcroppings and scattered stones (e.g. mid and upper slopes of BIF), red in colour |
| 4 | Extensive Banded Ironstone Formation outcroppings of limited depth (BIF crests) |

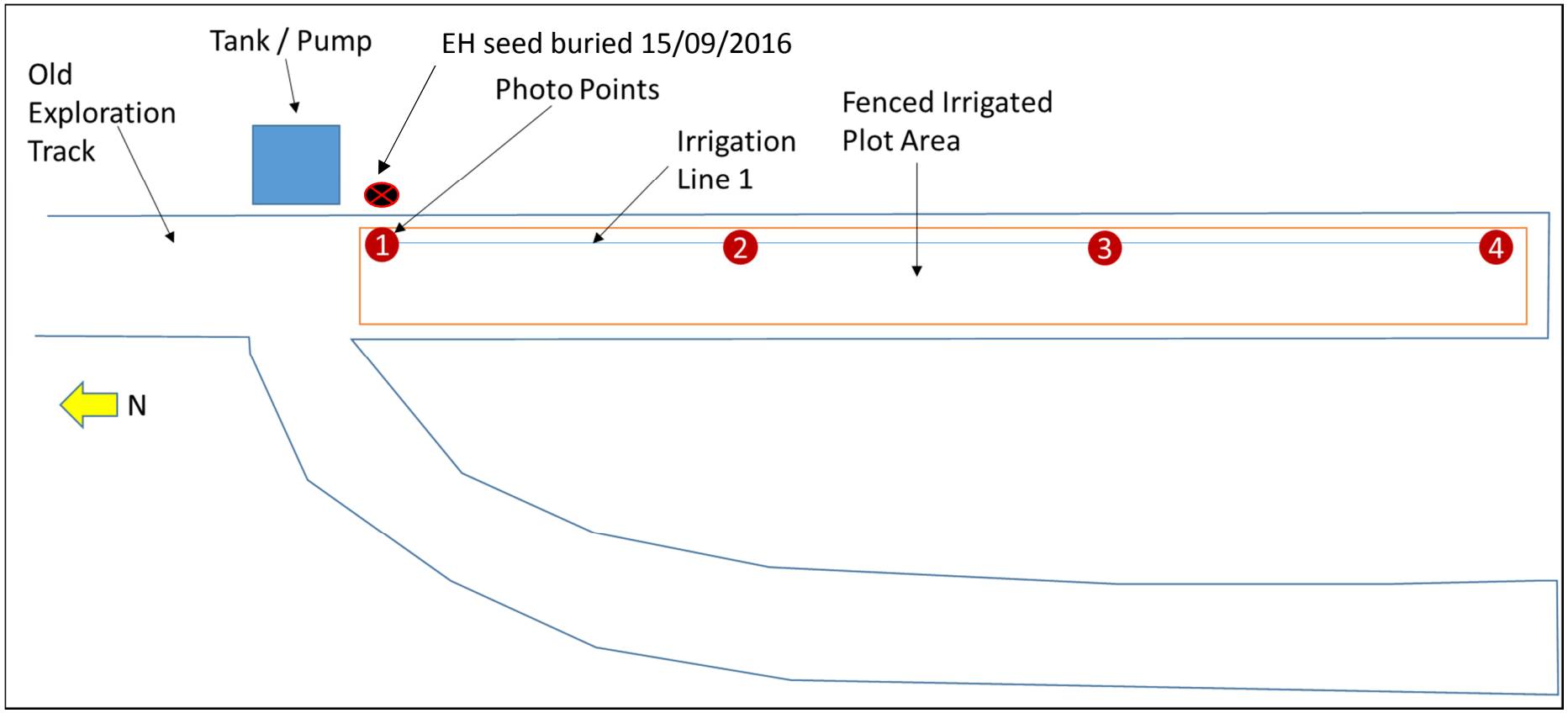

Tank / Pump
EH seed buried 15/09/2016
Old
Exploration
Track
Photo Points
Irrigation
Line 1
Fenced Irrigated
Plot Area
1
2
3
4
N

Photo Monitoring Points

| No.# | Details | Initial Photo (7/08/2016) |
|---|---|---|
| 1 | Start of Line 1 – Facing South | |

| | | |
|---|---|---|
| 2 | 1st Middle of Line 1 – Facing South | |

| | | |
|---|---|---|
| 3 | 2nd Middle of Line 1 – Facing South | |

| | | |
|---|---|---|
| 4 | End of Line 1 – Facing North | |

Rainfall

At the time of planting the ground was moist / damp due to recent rainfall which did also make digging holes easier. Appendix 2 shows rainfall from June to October 2016.

Due to moist conditions at the time of planting and after planting, watering the plants in was not necessary.

Mulch / Existing Vegetation

There was little mulch or existing vegetation across the entire plot.

Origin of plants

The plants were grown in nursery by Ben Croxford (Manager) at the Nuts about Natives Nursery from cuttings collected from Iron Hill during spring 2015.

Expertise of planters

Planters included Matt Hamilton (Senior Environmental Advisor MGM), Andrew Vear (Senior Field Project Lead Greening Australia) and Joseph Meadham (Casual Field Assistant Greening Australia). Both Joseph and Andrew had undertaken similar works for Greening Australia previously.

Condition of plants

The juvenile plants appeared to be in good condition with green healthy leaves. Heights ranged from approximately 6cm to 32cm. The soil contained within the pots was moist at the time of planting.

According to the key below, the seedling health was within Type 1 and 2.

| **Seedling Health Type** | **Description** |
|---|---|
| 1 | Excellent (e.g. multi-stemmed, new growth, vivid colour, >20cm height, healthy root mass which is not root-bound) |
| 2 | Moderate (e.g. single and multi-stemmed, a high proportion of new growth, atypical colour, 10-20cm in height, healthy root mass, slightly root bound) |
| 3 | Poor (e.g. single stemmed, minimal new growth, lighter in colour, <10cm height, mostly root bound, evidence of senescence) |

**Appendix 1 - Line Sequence Per Genotype**

| LINE1 | | LINE1 | | LINE1 | | LINE1 | |
|---|---|---|---|---|---|---|---|
| **PLANT #** | **GENOTYPE** | **PLANT #** | **GENOTYPE** | **PLANT #** | **GENOTYPE** | **PLANT #** | **GENOTYPE** |
| 1 | INF123 | 37 | INA58 | 78 | IND3 | 118 | INF70 |
| 2 | INF118 | 38 | INF234 | 79 | IND3 | 119 | INF71 |
| 3 | INF127 | 39 | INA24 | 80 | IND1 | 120 | INF77 |
| 4 | INF115 | 40 | INF232 | 81 | INF95 | 121 | INF73 |
| 5 | INF152 | 41 | INB129 | 82 | INF104 | 122 | INF79 |
| 6 | INF125 | 42 | INB141 | 83 | INF104 | 123 | IND96 |
| 7 | INF123 | 43 | INB154 | 84 | INF73 | 124 | IND77 |
| 8 | INF115 | 44 | IND11 | 85 | INF76 | 125 | INF73 |
| 9 | INF140 | 45 | IND11 | 86 | INF106 | 126 | IND94 |
| 10 | INF138 | 46 | INB129 | 87 | INF106 | 127 | IND96 |
| 11 | INF115 | 47 | IND3 | 88 | INF107 | 128 | IND96 |
| 12 | INF115 | 48 | INB17 | 89 | INF107 | 129 | IND58 |
| 13 | INF156 | 49 | INB11 | 90 | INF107 | 130 | IND55 |
| 14 | INF157 | 50 | INB99 | 91 | INF107 | 131 | IND63 |
| 15 | INF159 | 51 | INA58 | 92 | INF107 | 132 | IND58 |
| 16 | INF159 | 52 | INA58 | 93 | INF108 | 133 | IND96 |
| 17 | INF191 | 53 | INA58 | 94 | INF108 | 134 | IND50 |
| 18 | INF141 | 54 | INB99 | 95 | INF107 | 135 | IND50 |
| 19 | INF203 | 55 | INB129 | 96 | INF107 | 136 | IND65 |
| 20 | INF193 | 56 | INB129 | 97 | INF108 | 137 | IND80 |
| 21 | INF208 | 57 | INB139 | 98 | INF108 | 138 | INB17 |
| 22 | INF208 | 58 | INB148 | 99 | INF108 | 139 | IND63 |
| 23 | INF203 | 59 | IND1 | 100 | INF108 | 140 | IND58 |
| 24 | INF232 | 60 | IND100 | 101 | INF115 | 141 | IND52 |
| 25 | INF219 | 61 | INB78 | 102 | INF109 | 142 | IND56 |
| 26 | INF229 | 62 | INB68 | 103 | INF108 | 143 | IND59 |
| 27 | INF219 | 63 | INB52 | 104 | INF108 | 144 | IND85 |
| 28 | INF218 | 64 | INB129 | 105 | INF114 | 145 | IND79 |
| 29 | INF230 | 65 | INB129 | 106 | INF114 | 146 | IND69 |
| 30 | INF204 | 66 | INB129 | 107 | INF109 | 147 | IND59 |
| 31 | INA26 | 67 | INB129 | 108 | INF109 | 148 | IND59 |
| 32 | INA58 | 68 | INB129 | 109 | INF114 | 149 | IND50 |
| 33 | INF237 | 69 | INB130 | 110 | INF114 | 150 | IND52 |
| 34 | INF234 | 70 | INB130 | 111 | INF108 | 151 | IND54 |
| 35 | INF234 | 71 | INB130 | 112 | INF109 | 152 | IND56 |
| 36 | INA58 | 72 | INB148 | 113 | IND92 | 153 | IND53 |
| 37 | INA58 | 73 | INB148 | 114 | IND96 | 154 | IND57 |
| 38 | INF234 | 74 | INB141 | 115 | INF90 | 155 | IND61 |
| 39 | INA24 | 75 | IND1 | 116 | INF73 | 156 | IND76 |
| 40 | INF232 | 76 | INB156 | 117 | IND94 | 157 | IND60 |

| LINE1 | | LINE1 | | LINE1 | |
|---|---|---|---|---|---|
| **PLANT #** | **GENOTYPE** | **PLANT #** | **GENOTYPE** | **PLANT #** | **GENOTYPE** |
| 159 | IND66 | 200 | INB78 | 241 | IND70 |
| 160 | IND58 | 201 | INB97 | 242 | IND69 |
| 161 | IND54 | 202 | INB21 | 243 | IND71 |
| 162 | IND50 | 203 | INB99 | 244 | IND67 |
| 163 | IND56 | 204 | INB80 | 245 | IND43 |
| 164 | IND54 | 205 | INB129 | 246 | IND48 |
| 165 | IND73 | 206 | INB129 | 247 | IND50 |
| 166 | IND51 | 207 | INB127 | 248 | IND45 |
| 167 | IND43 | 208 | INB100 | 249 | IND43 |
| 168 | IND72 | 209 | INF214 | 250 | IND46 |
| 169 | IND74 | 210 | INF23 | 251 | IND43 |
| 170 | IND72 | 211 | INF232 | 252 | IND54 |
| 171 | IND83 | 212 | INF232 | 253 | IND50 |
| 172 | INB129 | 213 | IND45 | 254 | IND50 |
| 173 | INB129 | 214 | INB43 | 255 | IND50 |
| 174 | INB133 | 215 | INA11 | 256 | IND53 |
| 175 | INB130 | 216 | INF218 | 257 | IND51 |
| 176 | INB129 | 217 | INB154 | 258 | IND54 |
| 177 | IND46 | 218 | INA58 | 259 | IND54 |
| 178 | IND40 | 219 | INF219 | 260 | IND54 |
| 179 | IND40 | 220 | INA23 | 261 | IND66 |
| 180 | IND42 | 221 | INA58 | 262 | IND54 |
| 181 | IND45 | 222 | INA58 | 263 | IND57 |
| 182 | INB52 | 223 | INB148 | 264 | IND56 |
| 183 | INB52 | 224 | INB141 | 265 | IND58 |
| 184 | INB97 | 225 | INB174 | 266 | IND58 |
| 185 | INB100 | 226 | INA58 | 267 | IND58 |
| 186 | IND49 | 227 | INB156 | 268 | IND68 |
| 187 | INB37 | 228 | INF204 | 269 | IND66 |
| 188 | INB21 | 229 | INF141 | 270 | IND66 |
| 189 | INB43 | 230 | INF204 | 271 | IND69 |
| 190 | INB48 | 231 | INA24 | 272 | IND67 |
| 191 | INB41 | 232 | INB156 | 273 | IND67 |
| 192 | INB69 | 233 | INF217 | 274 | IND69 |
| 193 | INB78 | 234 | INB154 | 275 | IND69 |
| 194 | IND40 | 235 | INA69 | 276 | IND70 |
| 195 | INB78 | 236 | INF208 | 277 | IND69 |
| 196 | INB41 | 237 | INB148 | 278 | INB164 |
| 197 | INB99 | 238 | INB154 | 279 | IND57 |
| 198 | INB99 | 239 | INB164 | 280 | IND55 |

**Appendix 2 – Rainfall**

| Date | Period End | Jun-16 | Jul-16 | Aug-16 | Sep-16 | Oct-16 |
|---|---|---|---|---|---|---|
| 1 | 6:00 | 0 | 0 | 0 | 0.2 | 0.8 |
| 1 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 2 | 6:00 | 0 | 0 | 0 | 0 | 0.2 |
| 2 | 18:00 | 0 | 0.4 | 0 | 0 | 0 |
| 3 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 3 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 4 | 6:00 | 0 | 0 | 2.4 | 0 | 0 |
| 4 | 18:00 | 7 | 0 | 2.6 | 0 | 0 |
| 5 | 6:00 | 0 | 0 | 0.2 | 0 | 0 |
| 5 | 18:00 | 0.2 | 0 | 0 | 0 | 0 |
| 6 | 6:00 | 0 | 0 | 0.2 | 0 | 0 |
| 6 | 18:00 | 0.2 | 0 | 0.4 | 0 | 0 |
| 7 | 6:00 | 5.4 | 0 | 1.2 | 0 | 0 |
| 7 | 18:00 | 4.2 | 0 | 0.2 | 2.2 | 0 |
| 8 | 6:00 | 0.2 | 0 | 0 | 0 | 0 |
| 8 | 18:00 | 0 | 16.6 | 3.4 | 0 | 4.4 |
| 9 | 6:00 | 0 | 16.4 | 0.2 | 0 | 0.4 |
| 9 | 18:00 | 0.2 | 0.4 | 0 | 0 | 0 |
| 10 | 6:00 | 0 | 0.2 | 0 | 0 | 0 |
| 10 | 18:00 | 0 | 2 | 0.2 | 0 | 0 |
| 11 | 6:00 | 0 | 0.2 | 0 | 0 | 0 |
| 11 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 12 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 12 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 13 | 6:00 | 7 | 0 | 0 | 0 | 0 |
| 13 | 18:00 | 2 | 0 | 0 | 0 | 0 |
| 14 | 6:00 | 0.4 | 0 | 0 | 0 | 0 |
| 14 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 15 | 6:00 | 0.2 | 0 | 0 | 0 | 0.2 |
| 15 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 16 | 6:00 | 0 | 0 | 0 | 0 | 0 |

| Date | Period End | Jun-16 | Jul-16 | Aug-16 | Sep-16 | Oct-16 |
|---|---|---|---|---|---|---|
| 16 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 17 | 6:00 | 0.2 | 4.6 | 0 | 0 | 0 |
| 17 | 18:00 | 0 | 7.2 | 5.8 | 0 | 0 |
| 18 | 6:00 | 0 | 0.8 | 2.2 | 0 | 0 |
| 18 | 18:00 | 0 | 0.4 | 0.2 | 0 | 0 |
| 19 | 6:00 | 0 | 0 | 0 | 4 | 0 |
| 19 | 18:00 | 0 | 0.2 | 0 | 0 | 0 |
| 20 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 20 | 18:00 | 5.2 | 0.2 | 0 | 0 | 0.2 |
| 21 | 6:00 | 5.2 | 0 | 0 | 0 | 0 |
| 21 | 18:00 | 0 | 0.8 | 0 | 0 | 0 |
| 22 | 6:00 | 0.2 | 0.4 | 1.8 | 0 | 0 |
| 22 | 18:00 | 0 | 0 | 0.2 | 0 | 0 |
| 23 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 23 | 18:00 | 0.2 | 0 | 0 | 0.4 | 0 |
| 24 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 24 | 18:00 | 0 | 0 | 0 | 0 | 0 |
| 25 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 25 | 18:00 | 0.8 | 0.2 | 0 | 0 | 0 |
| 26 | 6:00 | 0.2 | 0 | 0 | 0 | 0 |
| 26 | 18:00 | 0.2 | 0 | 0 | 0 | 0 |
| 27 | 6:00 | 0 | 0 | 0 | 0 | 0 |
| 27 | 18:00 | 0 | 0 | 14.6 | 0 | 0 |
| 28 | 6:00 | 0 | 0 | 0.6 | 0 | 0 |
| 28 | 18:00 | 0 | 0 | 3.4 | 0 | 0 |
| 29 | 6:00 | 0.4 | 0.4 | 0 | 0 | 0 |
| 29 | 18:00 | 1.8 | 0 | 0 | 0 | 0 |
| 30 | 6:00 | 0.2 | 0 | 0 | 0 | 0 |
| 30 | 18:00 | 0 | 0.2 | 0 | 0 | 0 |
| 31 | 6:00 |  | 0 | 0 |  | 0 |
| 31 | 18:00 |  | 0.2 | 4.2 |  | 0 |
| **Total** | | **41.6** | **51.8** | **44** | **6.8** | **6.2** |

**Appendix H:**
***Lepidosperma gibsonii* research plan**

Scope of Work – FINAL FOR APPROVAL

Title

# Improving taxonomic resolution and evaluating the distribution of records in Mid-west *Lepidosperma* species


Proponents

Dr Paul Nevill and A/Prof Wardell-Johnson, ARC centre for Mine Restoration, Department of Environment and Agriculture, Curtin University

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## Background

The banded iron formation (BIF) ranges of the Yilgarn Craton in the Midwest and Goldfields regions of Western Australia are isolated ancient ranges set in a predominantly flat landscape. They form a small proportion of the total land area of the region and provide rare and fragmented habitat for endemic flora in comparison to the surrounding matrix (Gibson 2010; Gibson et al. 2012). Exemplifying patterns of plant diversity on BIF ranges are rare and geographically restricted *Lepidosperma* taxa. *Lepidosperma* is a genus of at least 73 species (Wallace 2016 and references therein) with ~16 currently of conservation concern in Western Australia (Barrett 2013):

*Lepidosperma* species are challenging to identify due to a lack of informative characters and molecular methods are critical tools for identifying ambiguous specimens and in studies of species diversity and relationships (e.g. Barrett 2012; Wallace 2016). An example of the difficulty in identifying *Lepidosperma* species and associated flora conservation issues is found in the *L. costale* species complex, in south-western Western Australia. Four species are currently in the *L. costale* species complex*; L. costale*, *L. benthanianum*, *L.* sp. Blue Hills (A.Markey & S.Dillon 3468) and *L. gibsonii* with the possibility of potentially new *L. species* Wanara form;

*Lepidosperma gibsonii* is of particular interest to Mount Gibson Mining Pty Ltd as it is both a rare and threatened species (Declared Rare Flora) and a requirement of Ministerial Statement 1045 that a *research program is carried out to confirm the taxonomic identity of L.gibsonii plants on the surrounding plains to the west of the Great Northern Highway*. It is noted that these areas for investigation are on lands beyond the boundary of tenements on which MGM is approved to operate.

This species is known from the Mt Gibson range and the adjacent pastoral leases. The most recent records of distribution are mapped by Parks & Wildlife. Concerns exist about morphological identifications of some populations of *L. gibsonii* based on specimens without genetic assessment. In addition, recent survey work (November 2015) has found specimens of both *L. gibsonii* and the potentially new *L.* sp Wanara form at the same locations, indicating that they may co-exist in some areas. This would appear to limit the reliability of current populations such that they may be unrepresentative of actual records of *L. gibsonii* occurring in situ. We will assess genetic variation in the *L. costale* species complex, including the potentially new *L.* sp Wanara form, using the Genotype by Sequencing method (GBS) (Elshire et al. 2011).

### Objectives

- In a sample of populations west of the Great Northern Highway, develop and test molecular methods for identification of *Lepidosperma gibsonii,* including admixed individuals (phase 1), and characterize the species status of ambiguous *Lepidosperma* specimens (phase 2).

### Management outcomes

These analyses will:

- Enable a more detailed understanding of the distribution and taxonomic make-up of records for the conservation priority species, *L. gibsonii*.
- Expand our understanding of the genetics of narrow endemic flora that can occur BIF.

Information from phase 1 of this this project will be used in phase 2, where additional targeted infill sampling of *Lepidosperma* may be conducted to adequately assess distribution limits/range overlaps of *L. gibsonii*, *L.* sp. Blue Hills (A.Markey & S.Dillon 3468) and *L. costale*, especially targeting potentially ambiguous populations currently suspected in the Wanara Rd area, west of GNH, where the potential new *L.* sp. Wanara form occurs.

**Methodology**

*Sampling:* If available and suitable for DNA extraction, we will use specimens collected during previous studies and held at the Botanic Gardens and Parks Authority. If unavailable or unsuitable for downstream molecular processes, and also where required for study completeness, we will conduct field sampling of plant material.

*DNA extraction:* DNA will be extracted using approaches previously optimised for *Lepidosperma* species (e.g. Wallace 2016).

*DNA sequencing/genotyping*: All samples will be assessed for genetic variation using Genotype by Sequencing method (GBS) (Elshire et al. 2011).

*Taxonomic review:* In conjunction with genetic work a taxonomic review, if required, to describe species characteristics.

We will use our DNA sequence data to test the distinction of species in the *L. costale* sp. complex, improve the resolution of relationships between them, and identify diagnostic regions for specimen identification including individuals of hybrid origin.

**Schedule**

An indicative schedule for the development of molecular tools for the identification of *Lepidosperma gibsonii* (Cyperaceae) is presented in Table 1.

**Table 1 Indicative schedule**

| Time | Activity |
|---|---|
| 1st February 2017-30th September 2017 (Phase 1) | • Select representative samples for analyses from existing collections and where required, conduct field sampling. Note MGM 2016 to enable targeted sampling for Phase 1 screening<br>• Obtain genetic data. Conduct preliminary data analyses<br>• Prepare interim report. |
| 1st October 2017 – 28th February 2018 (Phase 2) | • Depending on Phase 1 findings, conduct further sampling as required<br>• Undertake complete data analysis (optimisation of parameters, assessment of species limits and potential hybridisation)<br>• Undertake Taxonomic review if required<br>• Prepare final study report |

**Reporting**

An interim study report (eight months) would be prepared that documents the findings of Phase 1. The final study report (13 months) would present all findings and also present recommendations for further research, if required, and management implications.

**Funding**

The planning, implementation, and reporting of this proposal will be carried out as a collaborative project between Curtin University and Mt Gibson Mining Pty Ltd, with funding provided by Mt Gibson Mining Pty Ltd. Costs to complete this project will be up to:

Phase 1: $65,000 (inc GST)

Phase 2: $85,000 (inc GST)

Phase 1 payment will be made in full at commencement of the project (nominally 1st February 2017), with 50% of the balance of Phase 2 on MGM instruction at commencement of Phase 2 (1st October 2017) and 50% on completion the balance of Phase 2 (28th February 2018). This will enable a 0.5FTE Postdoctoral Research Fellow based at Curtin University. See section 2 for proposed budget.

**References**

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Gibson N et al. (2012) Patterns of plant diversity in ironstone ranges in arid south western Australia. Journal of Arid Environments 77, 25-31

Wallace M (2016) Polyploidy and genetic diversity in the *Lepidosperma Costale* species complex (Cyperaceae). PhD Thesis, University of Western Australia

**Budget**

| Item | Description | Cost ex GST |
|---|---|---|
| Personnel | -Postdoctoral Research Fellow Level ALB4 0.5 FTE 13 months including bioinformatics support and Curtin on costs of 42%.<br>-Taxonomic review *L. costale* complex | $75,000<br>$10,000 |
| Maintenance | -Field sampling including Botanical consultant, 4WD hire and accommodation<br>-DNA extraction,<br>-DNA sequencing of *L. costale, L. gibsonii, L.* sp. Blue Hills and *L. species* Wanara form samples | $10,000<br>$5,000<br>$36,400 |
| **Sub-Total** | | $136,400 |
| **GST (10%)** | | **$13,640** |
| **Total** | | **$150,040** |

**Appendix I:**
**Progress report on 2019 Translocation Results**

Mount Gibson Mining

# DARWINIA MASONII and LEPIDOSPERMA GIBSONII TRANSLOCATION REPORT

## December 2019 - December 2020

**Document Title:** DARWINIA MASONII & LEPIDOSPERMA GIBSONII TRANSLOCATION TRIAL REPORT
December 2019 – December 2020

**Date:** 12 March 2021

| Rev | Date | Revision description | By | Distribution |
|---|---|---|---|---|
| 0 | 5.02.2021 | Drafted | B.O'Grady | T. Collie<br>G. Hutton |
| 1 | 12.03.2021 | Finalised | B.O'Grady | DBCA; DWER |

Cover photos: *Darwinia Masonii* growing in a Translocation Plot on the Iron Hill Waste Rock Landform and *Lepidosperma gibsonii* growing in a Translocation Plot 500m north of the Iron Hill project area.

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# TABLE OF CONTENTS

1. EXECUTIVE SUMMARY ..... 1
2. INTRODUCTION ..... 3
3. SCOPE ..... 3
4. *DARWINIA MASONII* ..... 7
5. *LEPIDOSPERMA GIBSONII* ..... 7
6. TRANSLOCATION METHODOLOGY ..... 7
7. *DARWINIA MASONII* RESULTS ..... 9
7.1 Plot 4 ..... 9
7.2 Plot 6 ..... 10
7.3 Plot 14 ..... 12
7.4 Plot 16 ..... 14
7.5 Plot 17 ..... 15
7.6 Plot IH1WRL ..... 17
7.6.1 Plot IH1WRL-wet ..... 17
7.6.2 Plot IH1WRL-dry ..... 19
7.7 Plot 23 ..... 21
7.8 IHWRL treated seed trial area ..... 21
8. *LEPIDOSPERMA GIBSONII* RESULTS ..... 23
8.1 Plot 11 ..... 23
8.2 Plot 14 ..... 25
9. DISCUSSION ..... 28
9.1 *Darwinia masonii* ..... 28
9.2 *Lepidosperma gibsonii* ..... 30
10. REFERENCES ..... 32

# LIST OF FIGURES

Figure 1: Location of translocation plots and source material used at each Plot. ..... 6
Figure 2: Rainfall Records December 2019 to November 2020 ..... 8
Figure 3: Plant survival of *Darwinia masonii* at Plot 4 ..... 9
Figure 4: Percentage of growth within 10cm ranges for the periods 2016 – 2017 compared to 2017 – 2018, 2018 – 2019 and 2019-2020. ..... 10
Figure 5: Plant survival of *Darwinia masonii* at Plot 6 ..... 11
Figure 6: Percentage of growth within 10cm ranges ..... 12
Figure 7: Plant survival of *Darwinia masonii* at Plot 14 ..... 12
Figure 8: Percentage change in growth within 10cm ranges for the period 2016-2017 compared to 2017-2018, 2018-19 and 2019-20. ..... 13
Figure 9: Plant survival of *Darwinia masonii* at Plot 16 ..... 14
Figure 10: Percentage change in growth within 10cm ranges for the period 2016-2017, 2017-2018 and 2018-2019 and 2019-2020 ..... 15
Figure 11: Plant survival of *Darwinia masonii* at Plot 17 ..... 16
Figure 12: Percentage change in growth within 10cm ranges for the period 2017-2018, 2018-2019 and 2019-2020 ..... 17
Figure 13 Plant Survival of Darwinia masonii at Plot IH1WRL-wet ..... 18
Figure 14 Percentage change in growth within 10cm ranges for the period 2019-2020 ..... 19
Figure 15 Plant Survival of Darwinia masonii at Plot IH1WRL-dry ..... 20
Figure 16 Percentage change in growth within 10cm ranges for the period 2019-2020 ..... 21
Figure 17: Plant survival of *Lepidosperma gibsonii* at Plot 11 ..... 23
Figure 18: Percentage change in height growth within 10cm ranges for Plot 11 ..... 25
Figure 19: Percentage of growth in basal diameter within 2cm ranges for Plot 11 ..... 25
Figure 20: Plant survival of *Lepidosperma gibsonii* at Plot 14 ..... 26
Figure 21 Percentage change in height growth within 10cm ranges for Plot 14 ..... 27
Figure 22 Percentage of growth in basal diameter within 2cm ranges for Plot 14 ..... 27

# LIST OF TABLES

Table 1: Increase in height (growth amount in cm/year) of surviving plants at Plot 4 ..... 10
Table 2: Change in height of surviving plants at Plot 6 ..... 11
Table 3: Change in height of surviving plants at Plot 14 ..... 13
Table 4: Change in height of surviving plants at Plot 16 ..... 14
Table 5: Change in height of surviving plants at Plot 17 ..... 16
Table 6 Change in height of surviving plants at Plot IH1WRL-wet ..... 18
Table 7 Change in height of surviving plants at Plot IH1WRL-dry ..... 20
Table 8 *Darwinia masonii* germinants from smoke treated seed at IHWRL on 23 June 2020 ..... 22
Table 9: Growth in height of *Lepidosperma gibsonii* at Plot 11 from 2017 – 2018, 2018-2019 and 2019-2020 ..... 24
Table 10: Growth in basal diameter of *Lepidosperma gibsonii* at Plot 11 from 2017 – 2018, 2018 – 2019 and 2019-2020 ..... 25
Table 11 Growth in height of Lepidosperma gibsonii at Plot 14 from 2018-2020 ..... 26
Table 12 Growth in basal diameter of Lepidosperma gibsonii at Plot 14 from 2018 – 2020 ..... 27
Table 13: Summary results for all *Darwinia masonii* plots in 2020 ..... 30
Table 14 Summary results for all *Lepidosperma gibsonii* plots ..... 31

**LIST OF PLATES**

**Plate 1:** Darwinia masonii germinant at Iron Hill Project area

# LIST OF APPENDICES

## Appendix A – D.masonii Soil Seedbank Assessment Pilot Study and Phase II

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# 1. EXECUTIVE SUMMARY

The intent of this report is to provide the Department of Biodiversity, Conservation and Attractions (DBCA) with an annual update on the status of Mount Gibson Mining Limited's (MGM) progress towards achieving short term and medium term success criteria for translocations undertaken on two species of Declared Rare Flora (DRF), *Darwinia masonii* and *Lepidosperma gibsonii* across a variety of plots on the Mt Gibson Ranges. Since the commencement of the translocation program 4, 018 *Darwinia masonii* and 2, 961 *Lepidosperma gibsonii* have been planted at 7 *Darwinia masonii* and 2 *Lepidosperma gibsonii* plots. Monitoring undertaken during the reporting period focused on survival, growth, flowering and seed production as per the Approved Translocation Proposals.

In regards to *Darwinia masonii*, at the end of the reporting period, plot IH1WRL(wet) met both the short and medium term criteria for survival as the rate of survival was greater than 70% and more than 200 plants were recorded alive in the plot.

For the survival rate success criteria (>70%), plots 14 and 17 were just below the target (64% and 65% respectively). The other three plots ranged from 37% to 44% survival.

For the total plants per plot success criteria (>200 plants/plot), all plots achieved this target, accept plot 6 and plot IH1WRL(dry).

The plot that returned the highest survival rate was Plot IHWRL(wet) with a 90% survival rate from the 297 plants established in this plot. The lowest survival rate was Plot IHWRL(dry) with a 37% survival rate from the 316 plants established in this plot.

In regards to growth over the reporting period, Plot 14 returned the highest average growth of 34cm and Plot 4 returned the lowest average growth of 13cm, since the plots and any subsequent infill plants were established.

Overall, when compared to 2019, there was a decrease in the flowering rates at all plots. The 2019 combined average for flowering rates was 72%, the combined average for all plots decreased to 49% in 2020. The plot that recorded the highest flowering rate was Plot 17 with 78% of the 560 alive plants producing flowers. The plot that recorded the lowest flowering rate was Plot 16, with only 7% of the 242 alive plants producing flowers.

In mid-late 2020, the presence of viable seed in translocation plots was compared to naturally occurring populations by MBS Environmental through a pilot and phase II study (MBS, 2021). The results of this work are attached as Appendix A. The key finding from this research are reproduced below:

- *Results from translocation plot 4 (established in 2007) and plot 17 (established in 2017) indicate that the rate of seed fill and number of fruits produced by translocated D. masonii may increase with time and maturity of the occupants within translocation populations. The first two surveys indicated that, after ten years or less, a translocated population can produce abundant seed, which are dispersed by native insects and which have a fill rate (in the soil) consistent with (or in excess of) a natural population. These findings indicate a strong possibility that translocated populations can become self-sustaining by producing a potentially viable soil seedbank, as borne out by the observations of active recruitment in and around plot 4.*
- *Based on results from plot 17, three years appears insufficient for a translocation population to become potentially self-sustaining through soil seedbank recruitment. However, evidence shows that seedbank is accumulating in soils.*
- *Seed foraging by ants is likely a key driver in the abundance and distribution of viable seed in the soil seedbank of D. masonii. Therefore, fill rates of fruit harvested directly from plants are not considered reliable indicators for the fill rates of fruit found in the soil seedbank.*

At the end of the 2020 reporting period, a total of 2134 seedlings were surviving across all the translocation plots. MGM is obliged to offset 1321 seedlings taken in the establishment of the project. Even though the current quantity of alive seedlings at the translocation plots represents 162% of the

offset target, MGM propose to establish a further 1000 seedlings from nursery stock at the IHWRL plot. These additional seedlings will also be irrigated for the first 12 months to increase the likelihood of survival. The irrigation water will be sourced from the potable town supply in Perenjori.

In early 2019, as approved in an addendum to the translocation proposal, MGM broadcast 394g of smoke treated *D.masonii* seed across a portion of the IHWRL along the southern batter and surface of the waste rock landform. When inspected in mid-2020, a total of 86 *D.masonii* germinants were recorded across all 10 quadrats established for this trial.

In regards to *Lepidosperma gibsonii,* at the end of the reporting period, plants in plot 11 met the short term criteria for survival as the rate was greater than 50% and more than 200 plants were recorded alive in the plot. However, plants in plot 14 did not achieve the short term criteria targets with 32% survival and 186 plants recorded as alive. Across all plots, the average growth in height was 19cm, the average growth in basal diameter was 2.0cm and 76% were recorded as flowering.

## 2. INTRODUCTION

This report provides an annual update on the status of Mount Gibson Mining Limited's (MGM) *Darwinia masonii* and *Lepidosperma gibsonii* translocations across the Mt Gibson Ranges. The overall objective of this program is to implement species recovery actions and translocations proven conceptually by BGPA (2010) and Ruoss (2013) for *D. masonii* and *L. gibsonii* on a larger scale across the Mt Gibson Ranges. This report covers the period from the 31st December 2019 to 31st December 2020. The location of the plots and the source material used at each plot is shown by Figure 1.

In July 2019 a new *Darwinia masonii* plot was established on the southern batter of the Iron Hill Waste Rock Landform (IHWRL). This new plot included a mix of irrigated and non-irrigated seedlings, with 297 juveniles established under irrigation and a further 316 juveniles established via direct planting into the WRL. The total number of juveniles planted since inception of the program is 4,018.

In August 2019, 220 dead *Lepidosperma gibsonii* plants were infilled at plot 11 and plot 14, bringing the total number planted since establishing the program to 2,961.

## 3. SCOPE

This report aims to compare monitoring results against success criteria as per DBCA approved Translocation Proposals for each species as detailed below.

## Success Criteria

### *Darwinia masonii*

**Short Term 1- 2 years**

| Success Criteria | Failure Criteria |
|---|---|
| Greater than 200 individuals in each trial area (>70% survival) | Less than 200 individuals in each trial area (<70% survival) |

**Medium Term 2- 5 years**

| Success Criteria | Failure Criteria |
|---|---|
| Greater than 200 individuals in each trial area (>70% survival). | Less than 200 individuals in each trial area (<70% survival) |
| Flower production and seed set in surviving individuals at a rate equivalent to individuals growing naturally within the nearest TPFL. | Flower production and seed set of surviving individuals occurs at a lower rate compared to individuals growing naturally within the nearest TPFL. |
| Presence of viable seeds in soils at translocation plots with germination rates equivalent to naturally occurring populations. | Presence of viable seeds in soils at translocation plots with germination rates that are less than naturally occurring populations. |

### *Lepidosperma gibsonii*

**Short Term First 2 years**

| Success Criteria | Criteria for adaptive management |
|---|---|
| Greater than 200 individuals in each site (>50% survival) | Less than 200 individuals in each translocation site (<50% survival) |

Monitoring for survival has considered those which are evidently alive, those which are alive though appear to be in doubt (50/50 chance of survival) and those which are evidently dead.

As required by the approved Translocation Proposal, the number of *D. masonii* flowering has also been reported. Plants were recorded positive for flowering if they had one or more flowers. Some plants were flowering more than others, however counting all flowers per plant was considered impractical. Observations were also made for flowering of *L. gibsonii* as indicated by the presence of one or more flower stems on each plant.

For the purpose of comparing flower production and seed set of surviving individuals, MGM staff collected 1 infructescence from 80 *D. masonii* for comparison to infructescences from natural populations in November 2020. The focus of the collection was on those plots and plants which had survived since 2016, though small collections were also made from other younger plots and plants. BGPA were commissioned to undertake this analysis and compile a report. At the time of reporting, the results of this work were still being compiled by BGPA. The results will be presented in the 2021 annual report.

In addition, for the purpose of assessing viable seeds in soil profiles, the work outlined in Appendix A was completed by MBS Environmental over the second half of 2020.

Other measurements reported include the growth in height of both species and the growth in basal diameter of *L. gibsonii* of all surviving plants planted in 2016, 2017, 2018, 2019, 2020. Whilst not necessary for reporting as per the approved Translocation Proposals, these measurements have been included to provide an indication of growth and vitality of the plants and progress of the program. Height has been measured using a tape measure and rounding to the nearest 5cm. Basal diameter has been measured at the base of each plant using a tape measure and rounded to the nearest 1cm.

It should also be noted that some plants recorded negative growth, and this may have been due to human error or an actual reduction due to declining health or branches breaking due to natural occurrences. However, reporting negative growth is likely to skew the results of those plants showing positive growth. So, for this reason, zero growth throughout this report should be treated as zero or less.

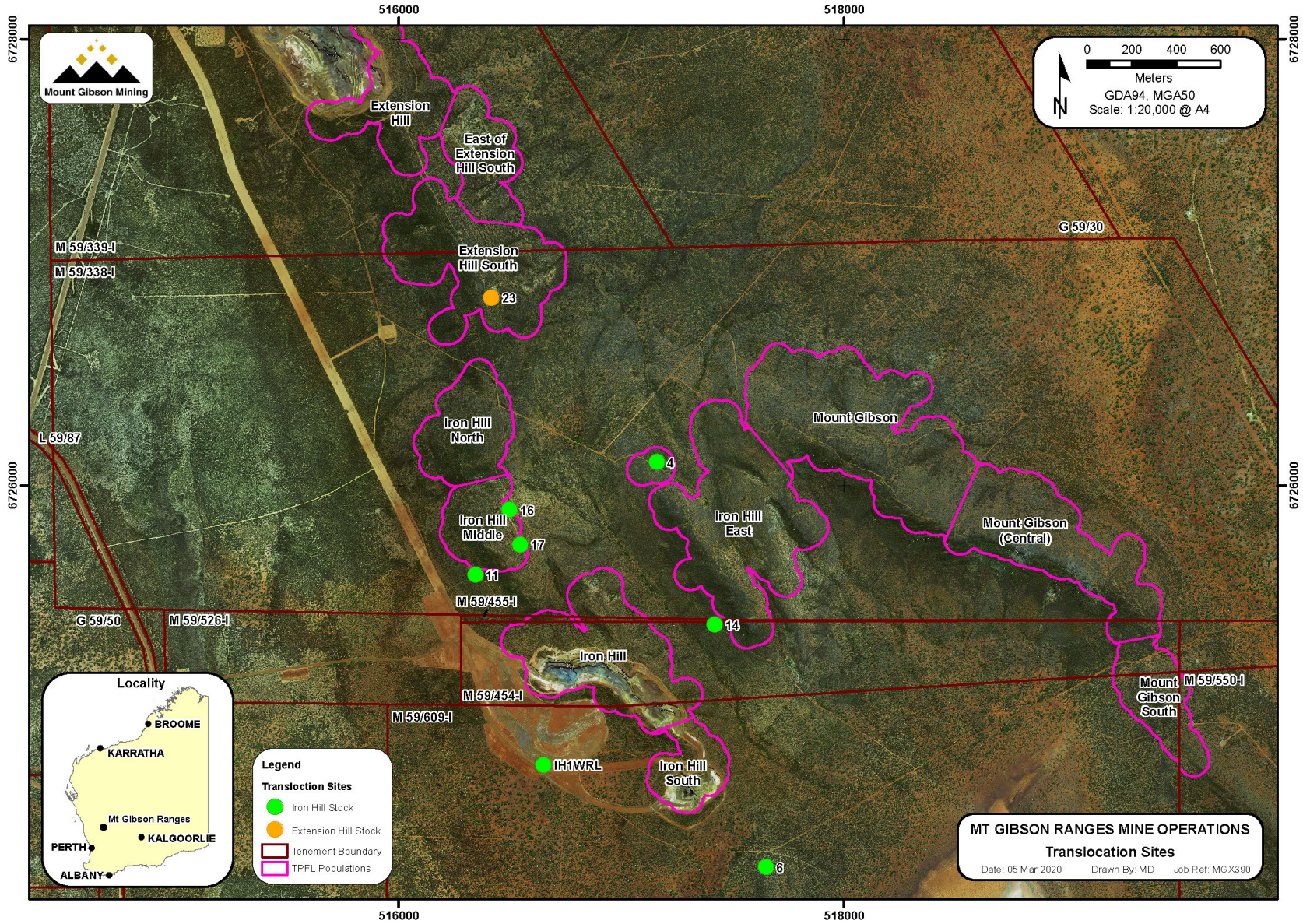



**Figure 1:** Location of translocation plots and source material used at each Plot.

# 4. *DARWINIA MASONII*

*Darwinia masonii* is an erect shrub which is endemic to the Mt Gibson Range. These plants typically grow to 1.5 – 3.0 m tall, with narrow leaves up to 1 cm long (McLean 2008). BGPA (2010) recorded the average stem growth as 0.4 mm/yr and the average height growth as 2.9 cm/yr.

The species exhibits physiological responses to weather conditions, with vegetative growth having been noted following summer rainfall events and physiological dormancy observed during hot, dry summer periods.

The flowering period for *D. masonii* is April to November, depending upon weather conditions, and fruits mature and dehisce by December (McLean 2008). Ants were observed by BGPA (2010) to be the primary seed disperser.

Previous translocation trials involving greenstock produced in a nursery from cuttings have shown a greater survival rate (81% after 8 years) in trials that were watered twice a month for the first two summers, compared to unwatered trials (average of 13% survival in BIF rock and BIF gravel sites, and no survival in sand and clay sites after 5 years).

# 5. *LEPIDOSPERMA GIBSONII*

*Lepidosperma gibsonii* appears to be restricted to the mid-west region of Western Australia where it occurs in the vicinity of the Mt Gibson Ranges, located approximately 80 kilometres (km) northeast of Wubin and 350 km north east of Perth. Within the Mt Gibson Ranges, *L. gibsonii* prefers slopes or gullies that provide increased water availability during rainfall events.

It is a fine-leaved herb (sedge), and grows up to 0.6 - 0.7 m high (Meissner and Caruso 2006, Barrett 2007). Its pale green culms are terete, scarcely finely ribbed and fully erect, and grow up to 45 cm tall. Flowering to seed production occurs over an 18 month period (BGPA, 2010). Flower development starts in late winter to early spring followed by a period of dormancy over summer until May-June when the flowers mature and release their pollen. BGPA (2010) found that evidence from population structure suggested a mean basal diameter growth rate of 2 – 2.5mm per year for seedlings and adults.

*Lepidosperma gibsonii* showed between 60-70% survival (9 months after planting) when grown on gravel or rocky substrates (BGPA 2010). Supplementary watering was not provided. A doctoral thesis (Ruoss 2013) further complements the BGPA (2010) research findings. Ruoss (2013) found that translocated *L. gibsonii* seedlings resulted in 59% and 63% survival (20 months after planting) when grown on a rocky ridge or gravel slope, respectively. Low levels of success occurred when seedlings were grown on sand plain (16% survival) or clay plain (2% survival) substrates. The greatest mortality occurred over the first summer and from thereafter survival was relatively stable up until 20 months (end of the study).

BGPA (2010) recommended that restoration/translocation areas for *L. gibsonii* should "*be shaped as slopes or gullies oriented with lower radiation receipt*" and include "*treatments varying shade and moisture*."

# 6. TRANSLOCATION METHODOLOGY

MGM (2018) provides a detailed description of the translocation methodology for each site including the following details:

- A sketch of the site including irrigation system layout,
- Initial photos of the plot,
- History of location,
- Method and date of planting,

- Substrate and growing medium,
- Number of plants,
- Origin of plants and expertise of planters, and
- Condition of plants prior to planting,

As detailed in MGM (2018), each plant is supplied with irrigation and drippers at a rate of 2L/per hour. Supplementary watering using the irrigation systems at each plot commenced in August 2016 and watering of *Darwinia masonii* has generally occurred at a rate of once or twice per week for 1 hour early in the morning. The watering rate was increased in comparison to the rate reported by BGPA (2010) to increase survival and growth during the summer period. *Lepidosperma gibsonii* was initially watered at a rate of once a week for one hour in the early morning and this was increased to 3 times a week for one hour in the early morning within 2 to 4 weeks of establishing Plot 11. The same rate was continued for *L. gibsonii* Plot 14. Irrigation at all plots ceased in June 2020, following the onset of winter rain patterns. No irrigation has occurred since.

The rainfall recorded in the district during the reporting period is shown by Figure 2. The long term annual average rainfall at Ninghan Station, located approximately 20km north of the Project, is 294.7mm (BOM 2018). The total rainfall in 2019/20 was 291mm at the Dalwallinu BOM site. This figure is close to the annual average. The February monthly total (76mm) was significantly higher than the long term average due to several summer storm events.

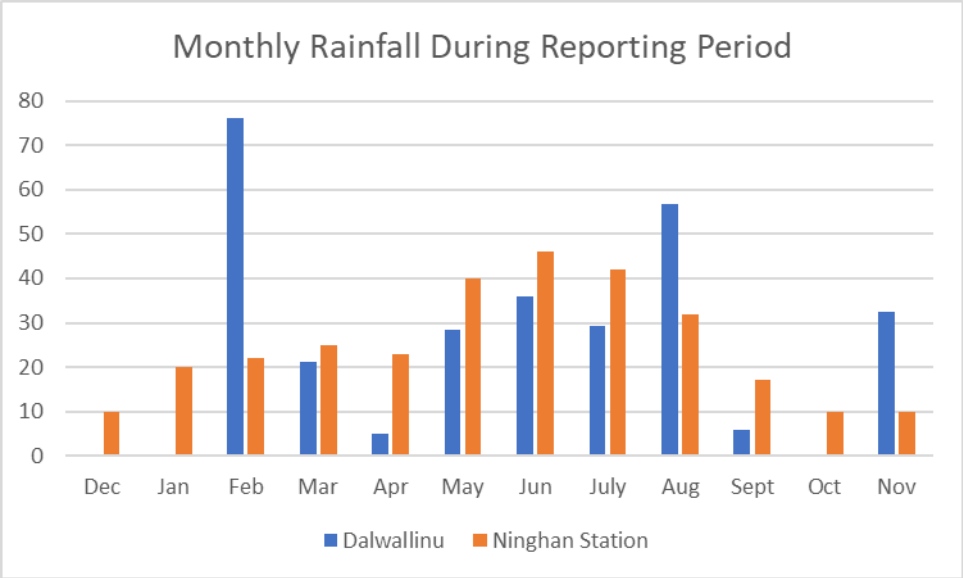



**Figure 2:** Rainfall Records December 2019 to November 2020

# 7. *DARWINIA MASONII* RESULTS

D.masonii specimens have been planted *en masse* at each plot in Figure 1, other than Plot 11. L.gibsonii are planted *en masse* at only Plots 11 and 14.

## 7.1 Plot 4

### Survival

As at the 31st of December 2020, approximately 54.0% (312 plants) of the 578 juveniles planted to date were alive and 26.6% (154) were dead; the balance (112 plants) were recorded as condition indeterminate ('50/50'). Figure 3 indicates that survival fluctuated between 54% to 89% throughout 2020, attributable to difficulty in determining whether plants have actually died using a visual assessment, or whether they have temporarily senesced in hot/dry weather.

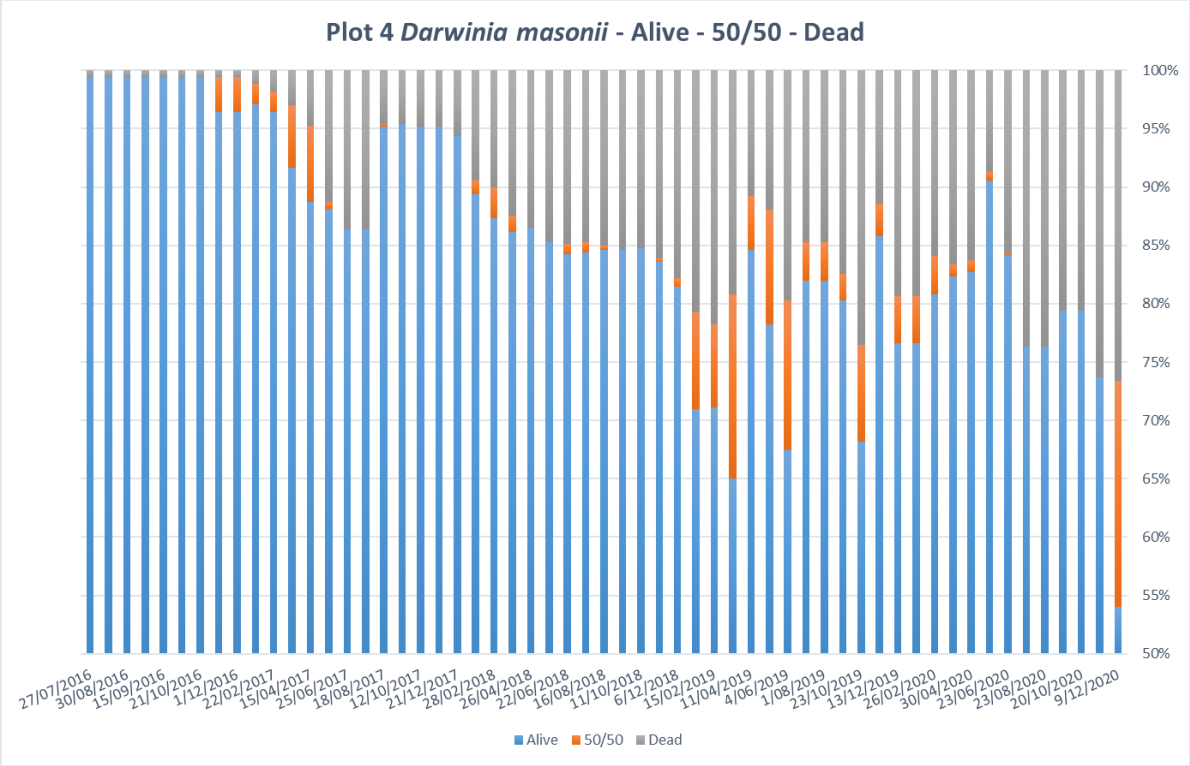



**Figure 3**: Plant survival of *Darwinia masonii* at Plot 4

### Growth

The average growth per plant was approximately 13cm over the 2020 reporting period, similar to the previous 2019 reporting period of approximately 11cm per plant (Table 1). Like the previous reporting period the majority of plant growth was positive ranged from 1 -20cm (Figure 4). In addition, a significant proportion (19%) of plants did not experience any growth during the reporting period.

**Table 1: Increase in height (growth amount in cm/year) of surviving plants at Plot 4**

| | Growth 2016 – 2017 (cm) | Growth 2017 – 2018 (cm) | Growth 2018-2019 (cm) | Growth 2019-2020 (cm) | Height (cm) Oct 2018 | Height (cm) Dec 2019 | Height (cm) Dec 2020 |
|---|---|---|---|---|---|---|---|
| **Average** | 11.0 (+/- 6.9) | 9.4 (+/- 10.1) | 10.7 (+/- 10.9) | 13.0 (+/- 11.9) | 39.5 | 41.5 | 44.6 |
| **Max** | 37.0 | 45.0 | 45.0 | 50.0 | 85.0 | 80.0 | 90.0 |
| **Min** | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 10.0 | 10.0 |

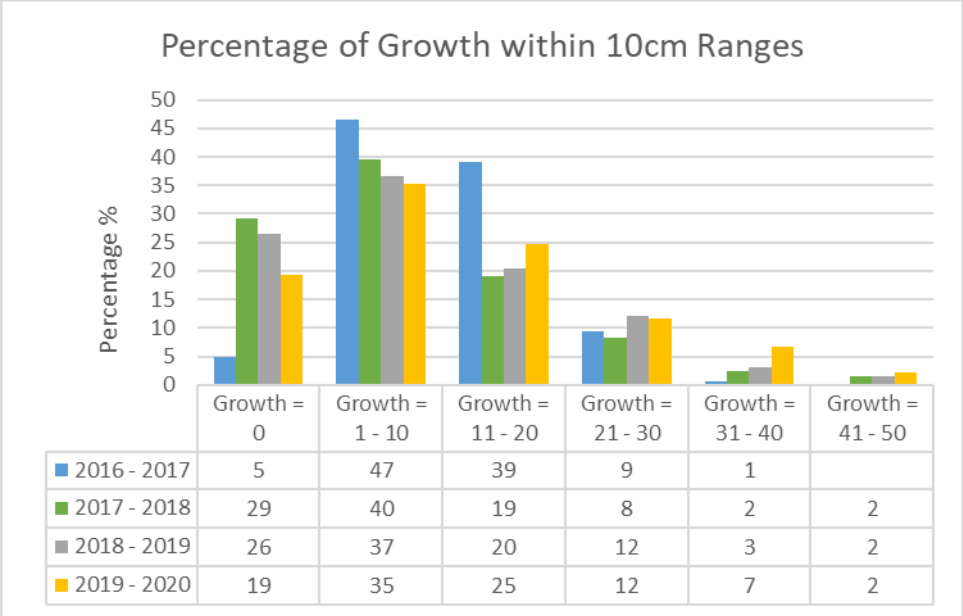



**Figure 4:** Percentage of growth within 10cm ranges for the periods 2016 – 2017 compared to 2017 – 2018, 2018 – 2019 and 2019-2020.

### Flowering

Of the 312 live plants monitored 138 were recorded as flowering, representing 44% of all live plants.

## 7.2 Plot 6

### Survival

As at the 31st December 2019, approximately 41% (131 plants) of the 316 juveniles planted were recorded alive and 52% (166 plants) were dead; the balance (67 plants) were recorded as condition indeterminate ('50/50') (see Figure 5). At the beginning of summer (December 2020), there was an increased number of plants that were rated subjectively as being in a 50/50 health condition, or dead. This was the first summer since irrigation was ceased and may indicate that the heavy loam soil profile at plot 6 may not be suitable for *D.masonii* growth without irrigation.

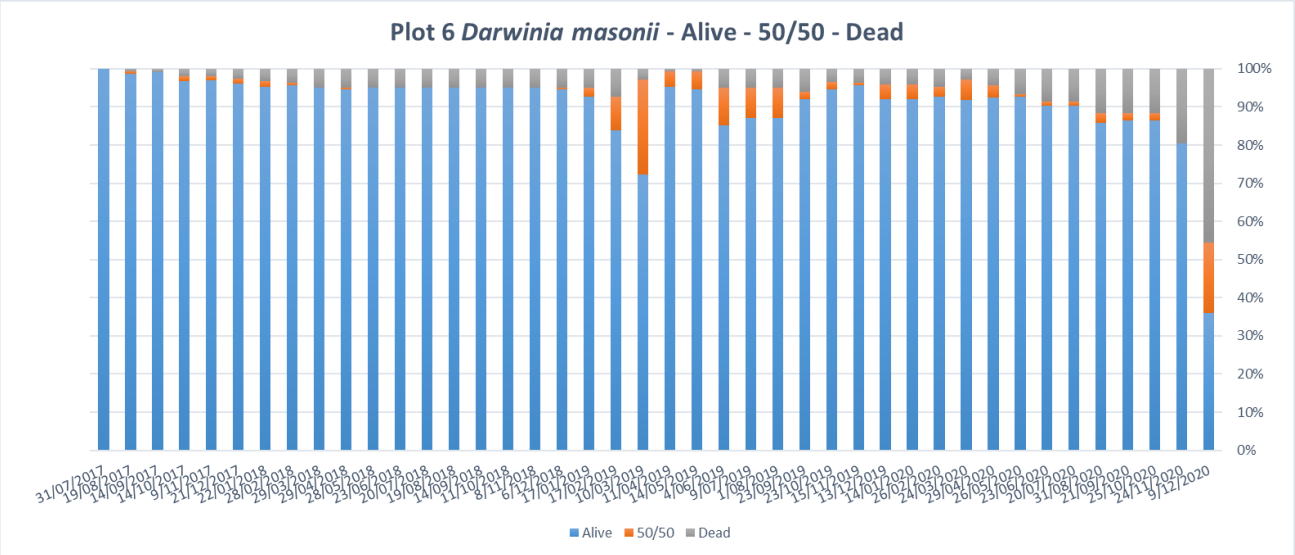


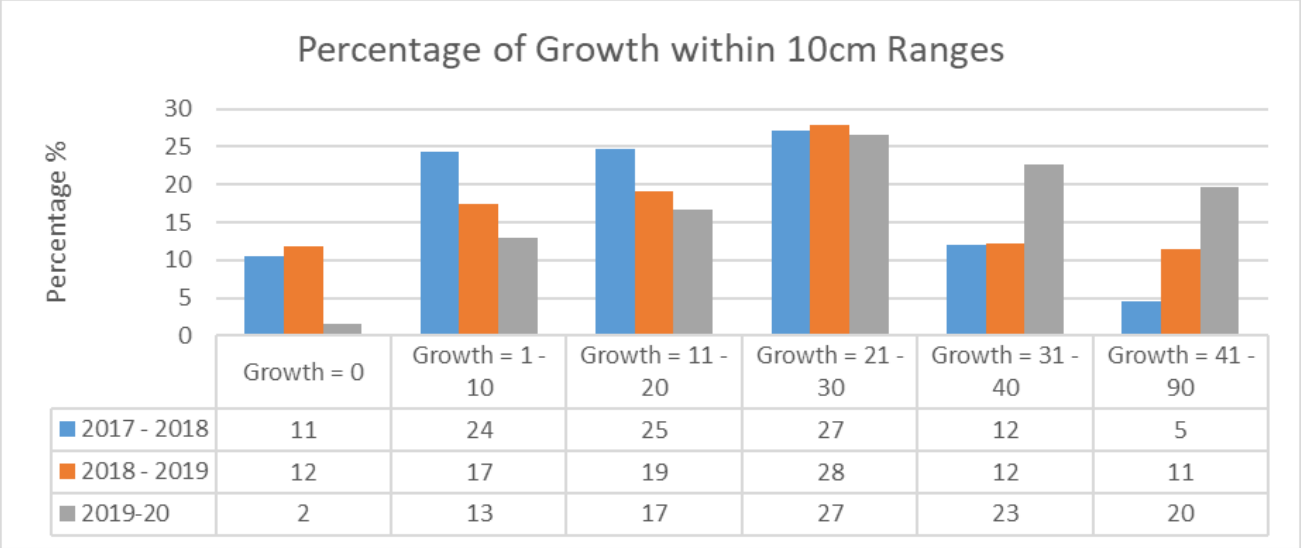

**Figure 5:** Plant survival of *Darwinia masonii* at Plot 6

## Growth

The average growth rate per plant was approximately 30.2cm over the 2020 reporting period, slightly higher than the previous 2019 reporting period of approximately 23cm per plant (Table 2). Like the previous reporting period the majority of plant growth was positive ranged from 1-30cm (Figure 6). In addition, a significant proportion (43%) of plants recorded growth rates which ranged from 31-90cm.

**Table 2:** Change in height of surviving plants at Plot 6

| | Growth 2017 – 2018 (cm) | Growth 2018 – 2019 (cm) | Growth 2019 – 2020 (cm) | Height (cm) Oct 2018 | Height (cm) Dec 2019 | Height (cm) Dec 2020 |
|---|---|---|---|---|---|---|
| **Average** | 20.0 (+/- 13.5) | 23.0 (+/- 15.7) | 30.2 (+/- 15.9) | 55.0 | 57.0 | 65 |
| **Max** | 85.0 | 85.0 | 100 | 120.0 | 120.0 | 135 |
| **Min** | 0.0 | 0.0 | 0.0 | 20.0 | 20.0 | 35 |




| | Growth = 0 | Growth = 1 - 10 | Growth = 11 - 20 | Growth = 21 - 30 | Growth = 31 - 40 | Growth = 41 - 90 |
|---|---|---|---|---|---|---|
| 2017 - 2018 | 11 | 24 | 25 | 27 | 12 | 5 |
| 2018 - 2019 | 12 | 17 | 19 | 28 | 12 | 11 |
| 2019-20 | 2 | 13 | 17 | 27 | 23 | 20 |

**Figure 6:** Percentage of growth within 10cm ranges

### Flowering

Of the 131 live plants, the minority were recorded as flowering (81 plants), representing 28% of all live plants in plot 6.

## 7.3 Plot 14

### Survival

As at 31st of December 2020, approximately 64% (504 plants) of the 792 juveniles planted to date were alive and 25% (198) were dead; the balance (90 plants) were recorded as condition intermediate ('50/50'). Figure 7 indicates that survival fluctuated between 64% to 90% throughout 2020, attributable to the difficulty in determining whether plants have actually died using a visual assessment, or whether they have temporarily senesced in either hot/dry, or cold/frost extremes of weather.

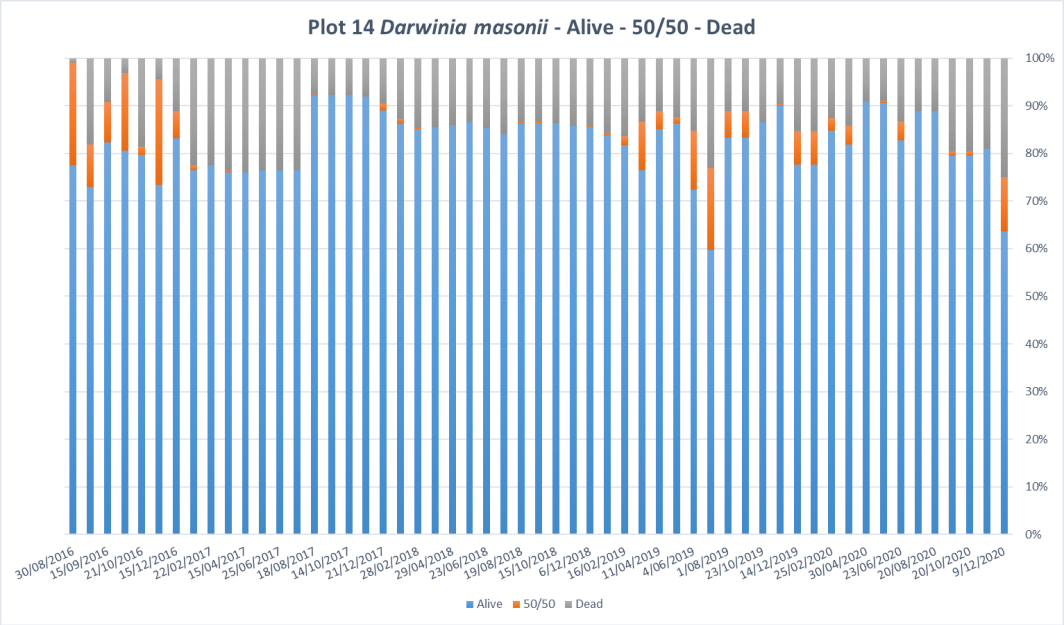


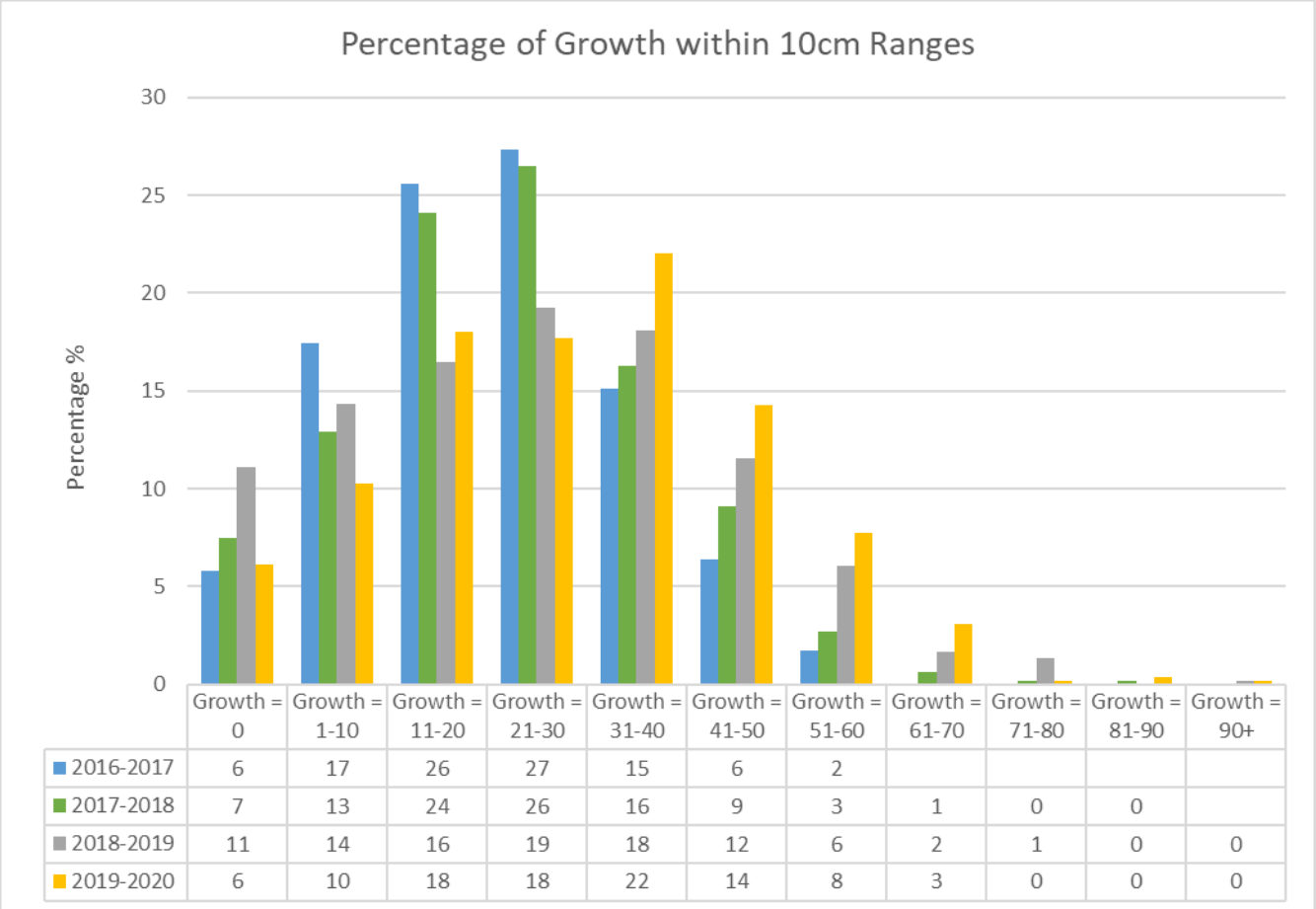

**Figure 7:** Plant survival of *Darwinia masonii* at Plot 14

## Growth

The average growth per plant was 31cm over the reporting period, which is a significant increase from the original 2017 reporting period of 21cm per plant (Table 3). Like the previous reporting period the majority of plant growth was positive and ranged from 1-50cm (Figure 8). In addition, there was an increase in the number of plants with growth rates in excess of 50cm (11%). There were 6% of plants that did not experience any growth during the reporting period.

**Table 3**: Change in height of surviving plants at Plot 14

| | Growth 2016 – 2017 (cm) | Growth 2017 – 2018 (cm) | Growth 2018 – 2019 (cm) | Growth 2019 – 2020 (cm) | Height (cm) Oct 2018 | Height (cm) Dec 2019 | Height (cm) Dec 2020 |
|---|---|---|---|---|---|---|---|
| **Average** | 21.0 (+/- 13.1) | 25.0 (+/- 14.9) | 27.0 (+/- 18.4) | 31 (+/- 17.7) | 61.0 | 63.0 | 67 |
| **Max** | 58.0 | 85.0 | 110.0 | 105 | 115.0 | 140.0 | 135 |
| **Min** | 0.0 | 0.0 | 0.0 | 0 | 10.0 | 15.0 | 10 |




| | Growth = 0 | Growth = 1-10 | Growth = 11-20 | Growth = 21-30 | Growth = 31-40 | Growth = 41-50 | Growth = 51-60 | Growth = 61-70 | Growth = 71-80 | Growth = 81-90 | Growth = 90+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2016-2017 | 6 | 17 | 26 | 27 | 15 | 6 | 2 | | | | |
| 2017-2018 | 7 | 13 | 24 | 26 | 16 | 9 | 3 | 1 | 0 | 0 | |
| 2018-2019 | 11 | 14 | 16 | 19 | 18 | 12 | 6 | 2 | 1 | 0 | 0 |
| 2019-2020 | 6 | 10 | 18 | 18 | 22 | 14 | 8 | 3 | 0 | 0 | 0 |

**Figure 8**: Percentage change in growth within 10cm ranges for the period 2016-2017 compared to 2017-2018, 2018-19 and 2019-20.

## Flowering

382 plants were recorded as flowering, representing 76% of all live plants. This is a slight decrease from the previous reporting period when 95% of live plants were flowering on plot 14.

## 7.4 Plot 16

### Survival

As at the 31st of December 2020, approximately 44% (242 plants) of the 547 juveniles planted to date were alive and 26% (62) were dead; the balance (161 plants) were recorded as condition intermediate ('50/50'). Figure 9 indicates that survival fluctuated between 44% to 91% throughout 2020, attributable to difficulty in determining whether plants have actually died using a visual assessment, or whether they have temporarily senesced in either hot/dry, or cold/frost extremes of weather. This is further illustrated through the significant increase in plants that were classified as 'condition intermediate' at the end of the reporting period.

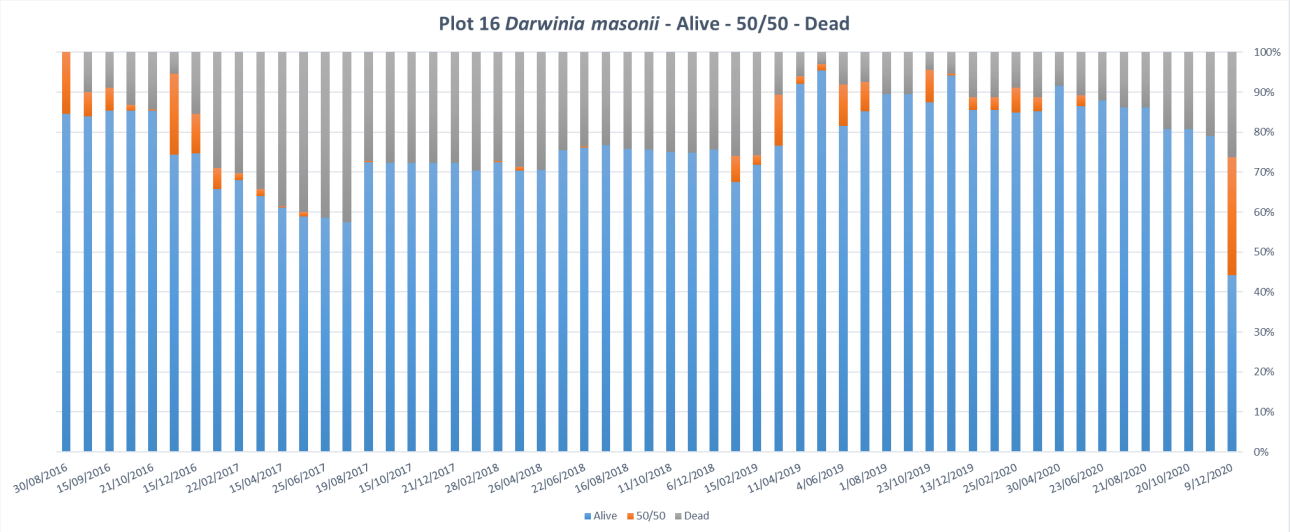


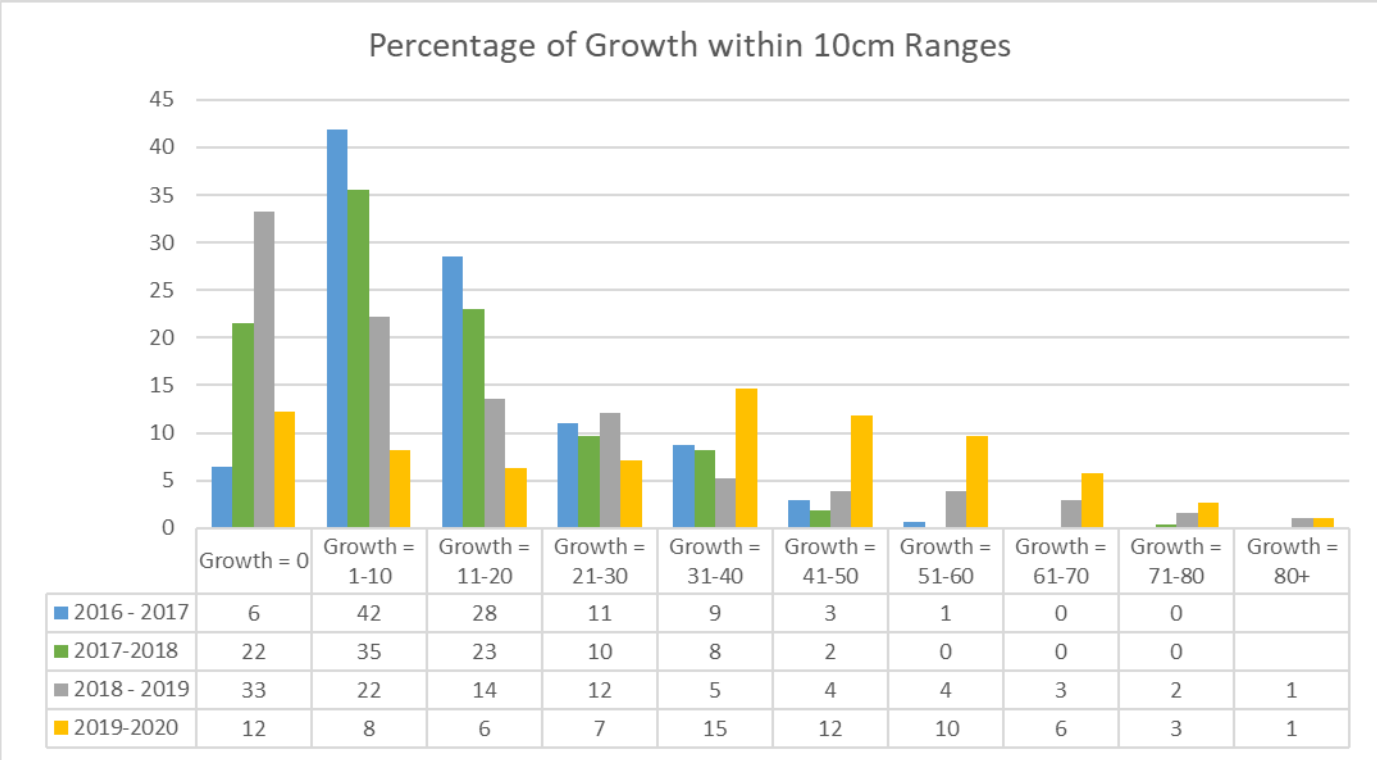

**Figure 9:** Plant survival of *Darwinia masonii* at Plot 16

### Growth

The average growth per plant since the seedlings were established in 2016, or infill plantings occurred in 2018, was approximately 34cm when measured at the end of the 2020 reporting period (Table 4). The plant growth was well distributed across all the various growth ranges (Figure 10). In addition, a significant proportion (12%) of plants did not experience any growth during the reporting period.

**Table 4:** Change in height of surviving plants at Plot 16

| | Growth 2016 – 2017 (cm) | Growth 2017 – 2018 (cm) | Growth 2018 – 2019 (cm) | Growth 2019 – 2020 (cm) | Height (cm) Oct 2018 | Height (cm) Dec 2019 | Height (cm) Dec 2020 |
|---|---|---|---|---|---|---|---|
| **Average** | 14.0 (+/- 11.7) | 12.0 (+/- 12.0) | 17.0 (+/- 21.0) | 34 (+/- 23.0) | 46.0 | 44.0 | 46 |
| **Max** | 52.0 | 77.0 | 131.0 | 93 | 110.0 | 150.0 | 105 |
| **Min** | 0.0 | 0.0 | 0.0 | 0 | 10.0 | 10.0 | 15 |




| | Growth = 0 | Growth = 1-10 | Growth = 11-20 | Growth = 21-30 | Growth = 31-40 | Growth = 41-50 | Growth = 51-60 | Growth = 61-70 | Growth = 71-80 | Growth = 80+ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2016 - 2017 | 6 | 42 | 28 | 11 | 9 | 3 | 1 | 0 | 0 | |
| 2017-2018 | 22 | 35 | 23 | 10 | 8 | 2 | 0 | 0 | 0 | |
| 2018 - 2019 | 33 | 22 | 14 | 12 | 5 | 4 | 4 | 3 | 2 | 1 |
| 2019-2020 | 12 | 8 | 6 | 7 | 15 | 12 | 10 | 6 | 3 | 1 |

**Figure 10:** Percentage change in growth within 10cm ranges for the period 2016-2017, 2017-2018 and 2018-2019 and 2019-2020

### Flowering

A relatively low number of all alive plants (7%) were recorded as flowering during the reporting period.

## 7.5 Plot 17

### Survival

As at the 31st of December 2020, approximately 65% (560 plants) of the 863 juveniles planted to date were alive and 11 % (98) were dead; the balance (205 plants) were recorded as condition indeterminate ('50/50'). Figure 11 indicates that survival fluctuated between 65% to 94%, attributable to difficulty in determining whether plants actually died using a visual assessment, or whether they have temporarily senesced in either hot/dry, or cold/frost extremes of weather. This is further illustrated through the significant increase in plants that were classified as 'condition intermediate' at the end of the reporting period.

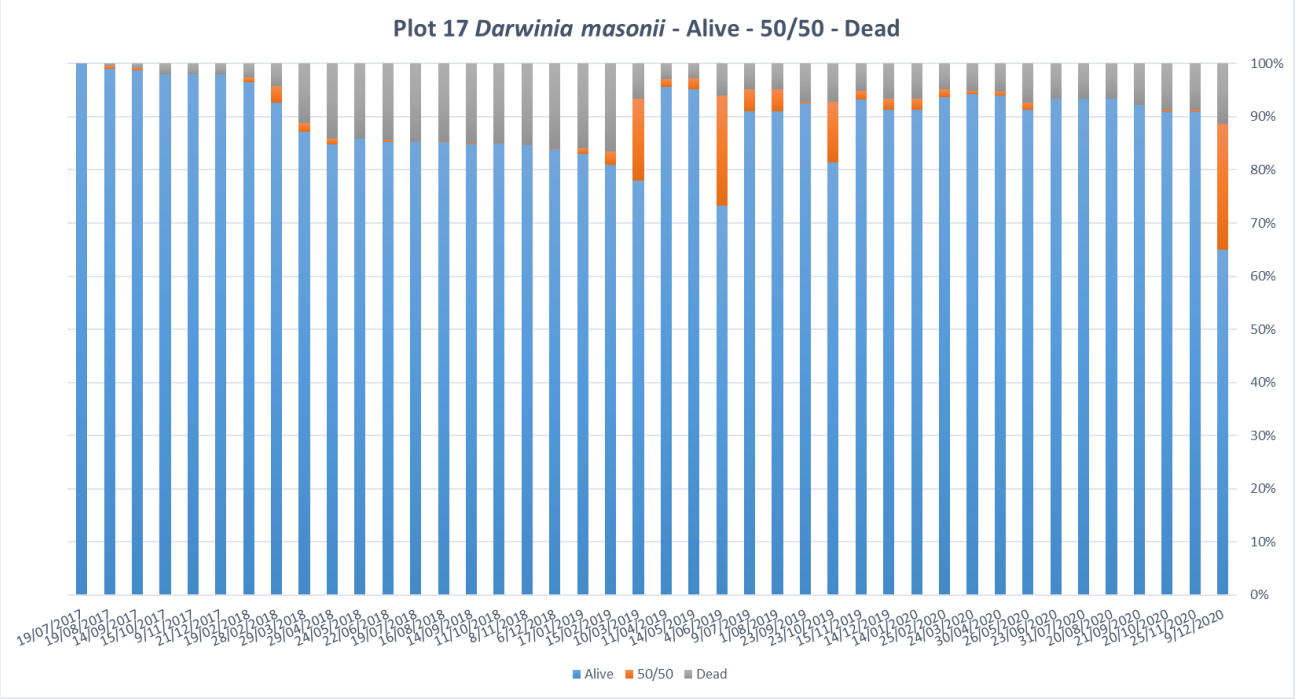


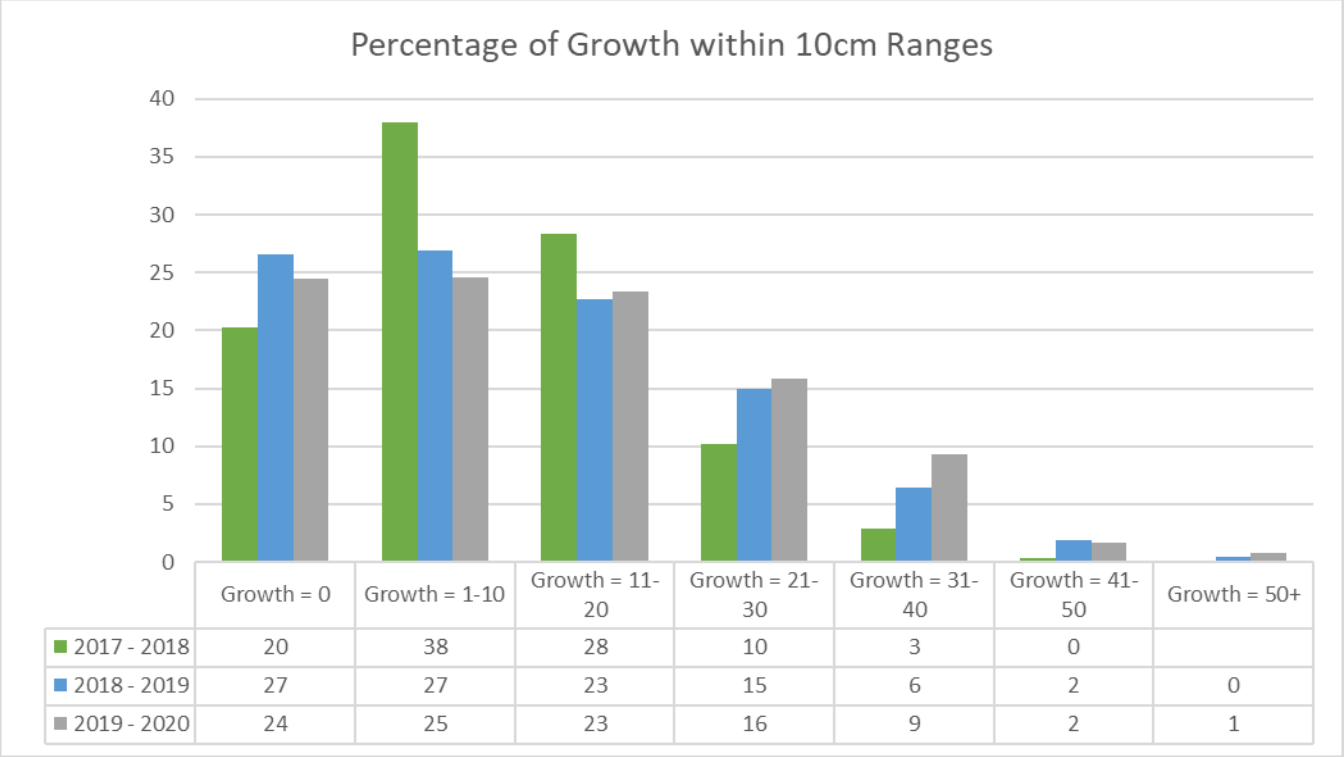

**Figure 11:** Plant survival of *Darwinia masonii* at Plot 17

## Growth

The average growth per plant was approximately 15cm over the 2020 reporting period, similar to the previous reporting period (Table 5). The majority of plant growth was positive ranged from 1-40cm (Figure 12). In addition, a significant proportion (24%) of plants did not experience any growth during the reporting period.

**Table 5:** Change in height of surviving plants at Plot 17

| | Growth 2017 – 2018 (cm) | Growth 2018 – 2019 (cm) | Growth 2019 – 2020 (cm) | Height (cm) Oct 2018 | Height (cm) Dec 2019 | Height (cm) Dec 2020 |
|---|---|---|---|---|---|---|
| **Average** | 12.0 (+/- 9.6) | 14.0 (+/- 12.5) | 15 (+/- 13.2) | 51.0 | 52.0 | 54.0 |
| **Max** | 45.0 | 55.0 | 65 | 100.0 | 100.0 | 105 |
| **Min** | 0.0 | 0.0 | 0 | 15.0 | 20.0 | 15.0 |




| | Growth = 0 | Growth = 1-10 | Growth = 11-20 | Growth = 21-30 | Growth = 31-40 | Growth = 41-50 | Growth = 50+ |
|---|---|---|---|---|---|---|---|
| 2017 - 2018 | 20 | 38 | 28 | 10 | 3 | 0 | |
| 2018 - 2019 | 27 | 27 | 23 | 15 | 6 | 2 | 0 |
| 2019 - 2020 | 24 | 25 | 23 | 16 | 9 | 2 | 1 |

**Figure 12:** Percentage change in growth within 10cm ranges for the period 2017-2018, 2018-2019 and 2019-2020

### Flowering

The majority of plants (78%) were recorded as flowering during the reporting period.

## 7.6 Plot IH1WRL

A new plot was established on the Iron Hill waste rock landform in July 2019. The plot consists of 300 juvenile *Darwinia masonii* that were irrigated at the same frequency as all other irrigation plots until mid-2020. In addition, a further 300 juvenile *Darwinia masonii* were established in the same location, these juveniles were not irrigated.

#### 7.6.1 Plot IH1WRL-wet

### Survival

As at the 31st of December 2020, approximately 90% (268 plants) of the 297 juveniles planted to date were alive and 8 % (24) were dead; the balance (5 plants) were recorded as condition indeterminate ('50/50'). Figure 13 indicates that survival fluctuated between 90% and 100%. This result was encouraging given that irrigation to all plants ceased in mid-2020.

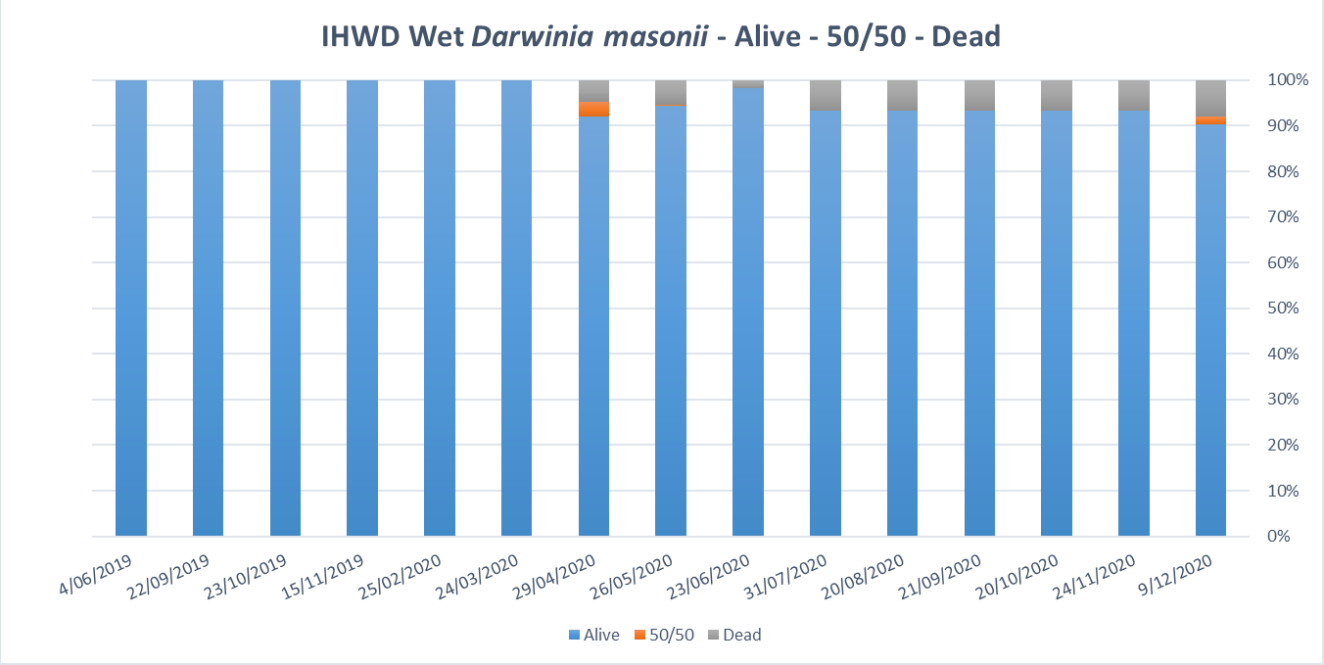



**Figure 13** Plant Survival of Darwinia masonii at Plot IH1WRL-wet

## Growth

The average growth per plant was approximately 20cm over the 2020 reporting period (Table 6). The majority of plant growth was positive ranged from 1-40cm (Figure 14). In addition, a small proportion (10%) of plants either did not experience any growth, or grew greater than 40cm during the reporting period.

**Table 6** Change in height of surviving plants at Plot IH1WRL-wet

| | Growth 2019 – 2020 (cm) | Height (cm) Dec 2020 |
|---|---|---|
| **Average** | 20(+/- 12) | 64.0 |
| **Max** | 55 | 115.0 |
| **Min** | 0 | 15.0 |

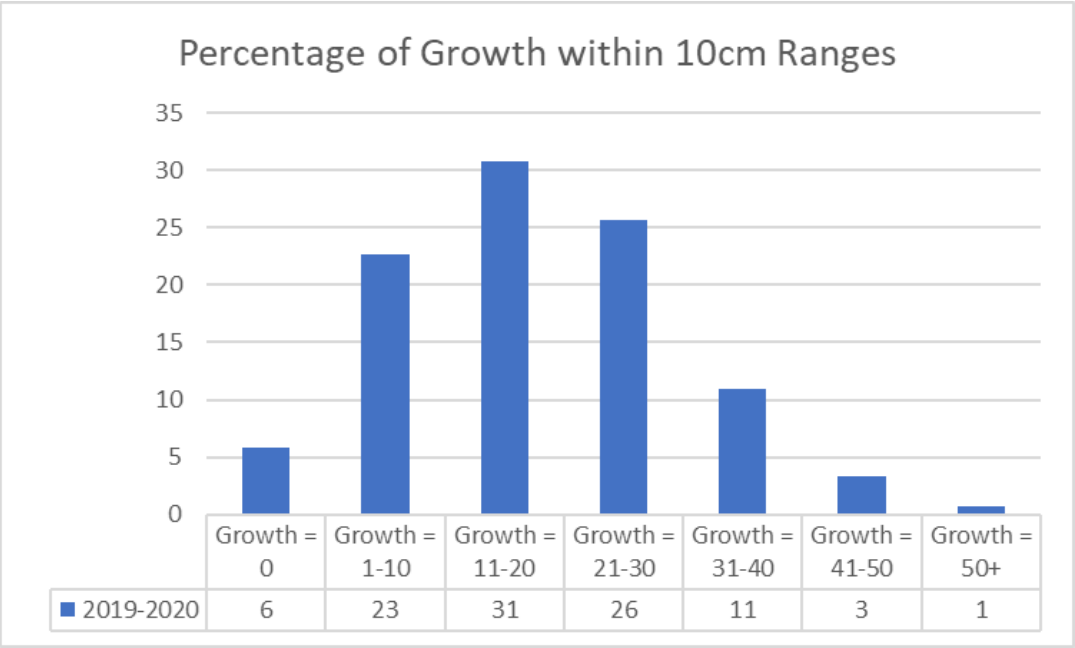



**Figure 14** Percentage change in growth within 10cm ranges for the period 2019-2020

## Flowering

The majority of plants (63%) were recorded as flowering during the reporting period.

### 7.6.2 Plot IH1WRL-dry

## Survival

As at the 31st of December 2020, approximately 37% (117 plants) of the 316 juveniles planted to date were alive and 63% (199) were dead; none of the plants were recorded as condition indeterminate ('50/50'). Figure 15 indicates that survival gradually decreased from 90% down to stabilising near 40% within 9 months of the seedlings being established. This result was expected and is encouraging, given the translocation plot is established on the southern face of a waste rock landform soil profile and has never been irrigated.

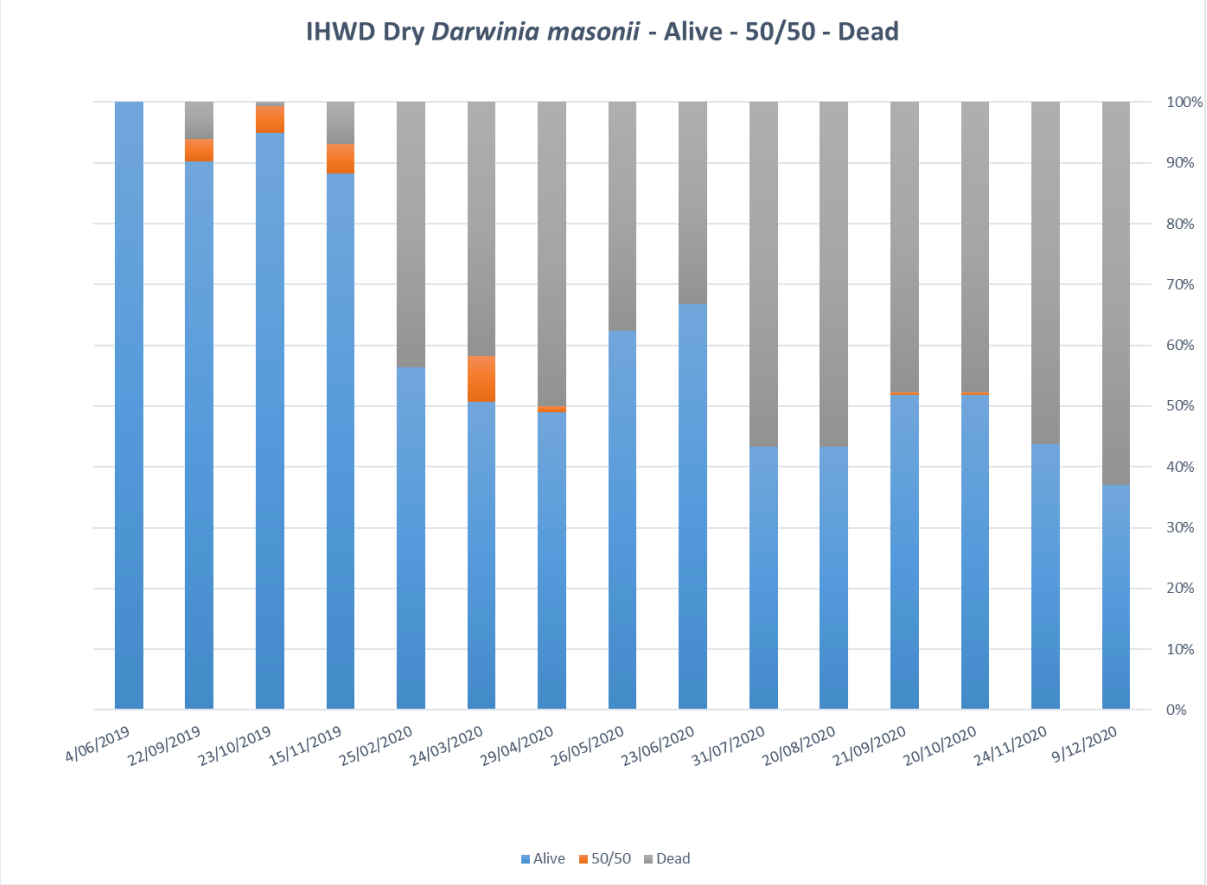



**Figure 15** Plant Survival of Darwinia masonii at Plot IH1WRL-dry

## Growth

The average growth per plant was approximately 21cm over the 2020 reporting period (Table 7). The majority of plant growth was positive ranged from 1-40cm (Figure 16). In addition, a small proportion (13%) of plants did not experience any growth.

**Table 7** Change in height of surviving plants at Plot IH1WRL-dry

| | Growth 2019 – 2020 (cm) | Height (cm) Dec 2020 |
|---|---|---|
| **Average** | 21(+/- 12) | 64.0 |
| **Max** | 75 | 110.0 |
| **Min** | 0 | 30.0 |

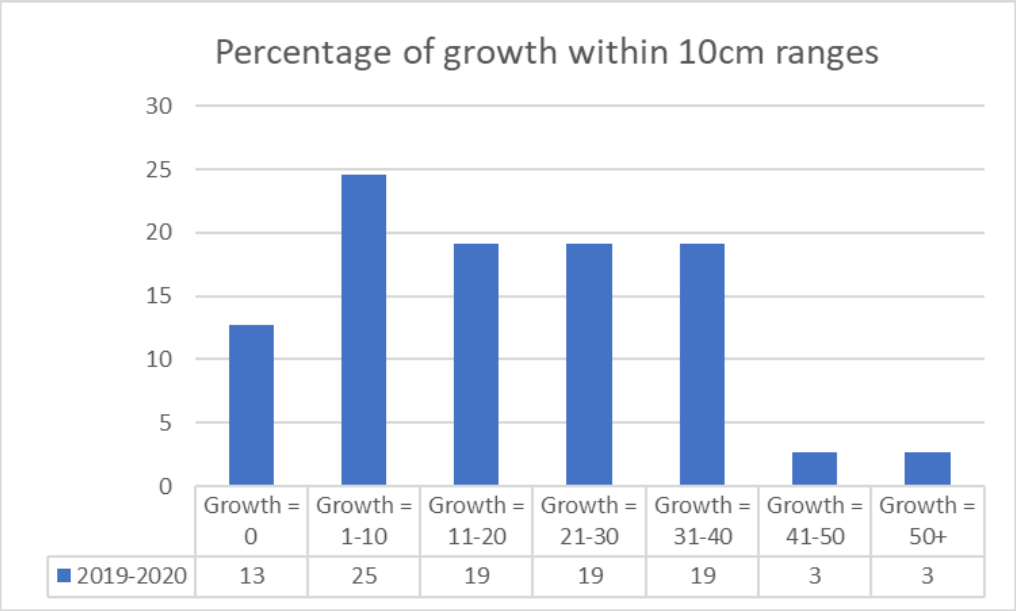



**Figure 16** Percentage change in growth within 10cm ranges for the period 2019-2020

### Flowering

Half of the plants (50%) were recorded as flowering during the reporting period.

## 7.7 Plot 23

Plot 23 experienced a low rate of survival since it was established with a significant decrease during the first summer and a continued steady decline (as last reported in 2019). Due to the low rate of performance, irrigation was removed from Plot 23 in late 2018 and the plot was not monitored during the reporting period.

## 7.8 IHWRL treated seed trial area

In early 2019, as approved in an addendum to the translocation proposal, MGM broadcast 394g of smoke treated *D.masonii* seed across a portion of the IHWRL along the southern batter and surface of the waste rock landform. The seed was evenly divided into 10 portions (39g / plot) and broadcast over 10 separate 100m2 quadrats. The seed was mixed with 4 parts soil to 1 part seed to assist with even distribution.

When inspected in mid-2020, a total of 86 *D.masonii* germinants were recorded across all quadrats as outlined below in table 8.

Each quadrat will be inspected again in the 2021 reporting period for further signs of germination and ongoing survival. An example of one of the germinants is illustrated below in Plate 1.

**Plate 1** *Darwinia masonii* germinant at Iron Hill Project area

**Table 8** *Darwinia masonii* germinants from smoke treated seed at IHWRL on 23 June 2020

| **Quadrat Number** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Number of germinants** | 9 | 11 | 2 | 2 | 12 | 1 | 3 | 10 | 16 | 20 |

# 8. *LEPIDOSPERMA GIBSONII* RESULTS

## 8.1 Plot 11

### Survival

As at 31st of December 2020, approximately 73% (1738 plants) of the 2385 juveniles planted to date were alive and 17% (74) were dead; the balance (239 plants) were recorded as condition indeterminate ('50/50'). Figure 17 indicates that the survival fluctuated between 73% to 98% throughout 2020, attributable to the difficulty in determining whether plants have actually died using a visual assessment, or whether they have temporarily senesced in either hot/dry, or cold/frost extremes of weather.

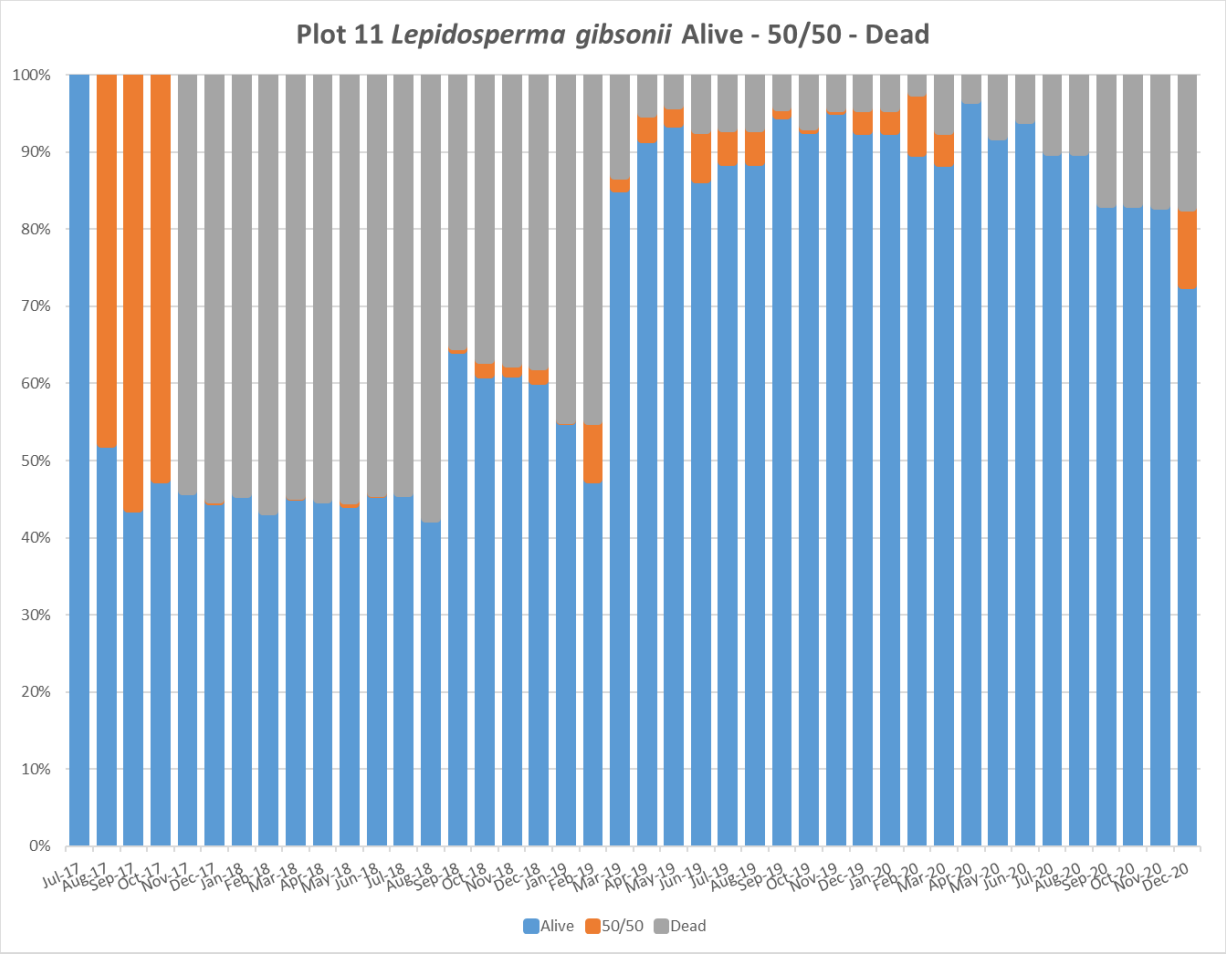



**Figure 17:** Plant survival of *Lepidosperma gibsonii* at Plot 11

### Growth

The average growth per plant was approximately 15cm over the 2020 reporting period (Table 8). The majority of plant growth was positive ranged from 1-30cm (Figure 18). In addition, a significant proportion (23%) of plants did not experience any growth during the reporting period.

Approximately 66% of plants showed expansions in basal diameter widths of between 1-6cm over the 2020 reporting period (Table 9). In addition, a significant proportion (30%) of plants showed either zero growth, or a reduction in basal diameter width (Figure 19).

**Table 9:** Growth in height of *Lepidosperma gibsonii* at Plot 11 from 2017 – 2018, 2018-2019 and 2019-2020

| | Growth 2017 – 2018 (cm) | Growth 2018 – 2019 (cm) | Growth 2019 – 2020 (cm) | Height (cm) Oct 2018 | Height (cm) Oct 2019 | Height (cm) Oct 2020 |
|---|---|---|---|---|---|---|
| **Average** | 11 (+/- 13.2) | 15.0 (+/- 11.6) | 15 (+/- 12.1) | 42.0 | 33.0 | 36 |
| **Max** | 50.0 | 60.0 | 60 | 70.0 | 70.0 | 75 |
| **Min** | 0.0 | 0.0 | 0 | 10.0 | 10.0 | 10 |

**Table 10:** Growth in basal diameter of *Lepidosperma gibsonii* at Plot 11 from 2017 – 2018, 2018 – 2019 and 2019-2020

| | Growth 2017 – 2018 (cm) | Growth 2018-2019 (cm) | Growth 2019-2020 (cm) | Basal Diameter (cm) Oct 2018 | Basal Diameter (cm) Dec 2019 | Basal Diameter (cm) Dec 2020 |
|---|---|---|---|---|---|---|
| **Average** | 1.6 (+/- 1.7) | 1.4 (+/- 1.7) | 1.9 (+/- 2.0) | 4.4 | 4.2 | 4.8 |
| **Max** | 8.0 | 11.0 | 11 | 12.0 | 13.0 | 14 |
| **Min** | 0.0 | 0.0 | 0 | 1.0 | 0.0 | 1 |

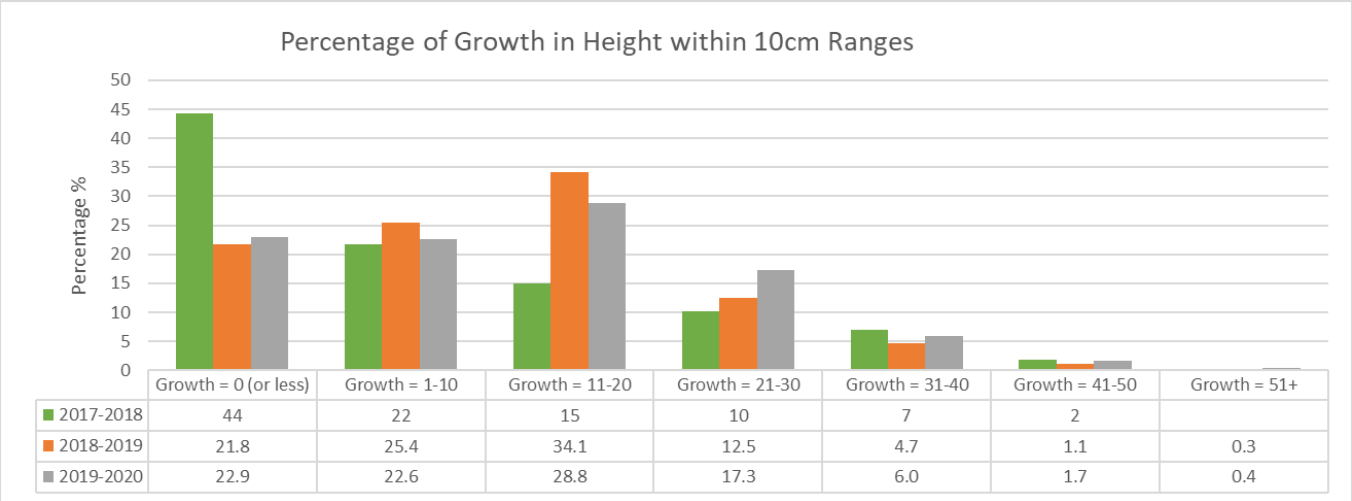



**Figure 18:** Percentage change in height growth within 10cm ranges for Plot 11

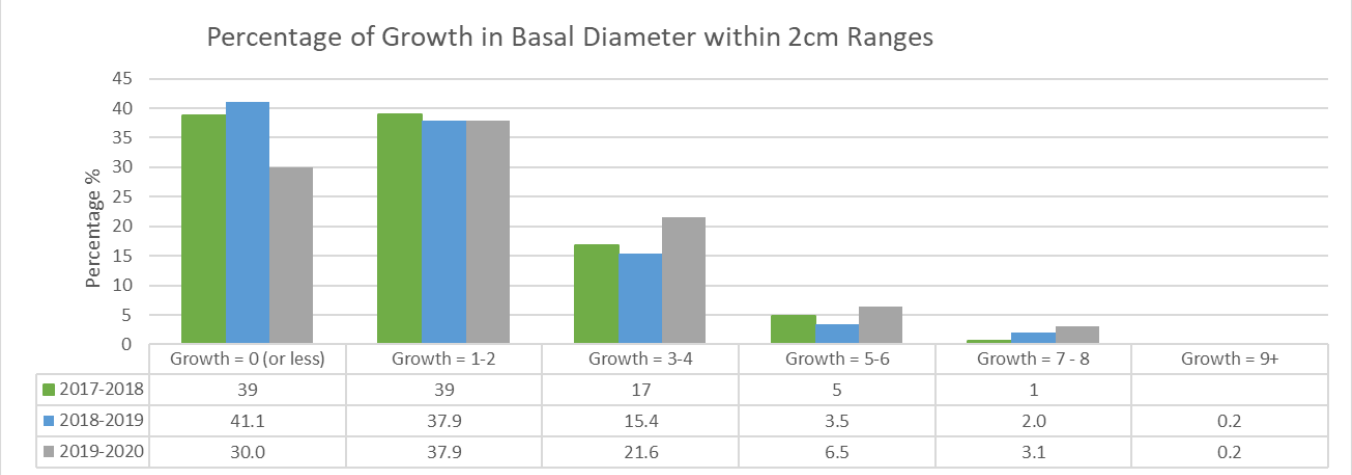



**Figure 19:** Percentage of growth in basal diameter within 2cm ranges for Plot 11

### Flowering

The majority of plants (82%) were recorded as flowering during the reporting period.

## 8.2 Plot 14

### Survival

As at 31st of December 2020, approximately 32% (186 plants) of the 576 juveniles planted to date were alive and 54% (313) were dead; the balance (77 plants) were recorded as condition indeterminate ('50/50'). Figure 20 indicates that the survival gradually reduced from 86% to 32%

throughout 2020. This reduction may be attributable to the difficulty in determining whether plants have actually died using a visual assessment, or whether they have temporarily senesced in either hot/dry, or cold/frost extremes of weather. In addition, *L.gibsonii* individuals in plot 14 may have temporarily senesced, or permanently deceased, following cessation of the irrigation system in mid-2020. Assessments made in winter 2021 will confirm whether the reduction in alive plant numbers is a temporary seasonal response, or permanent reduction in numbers.

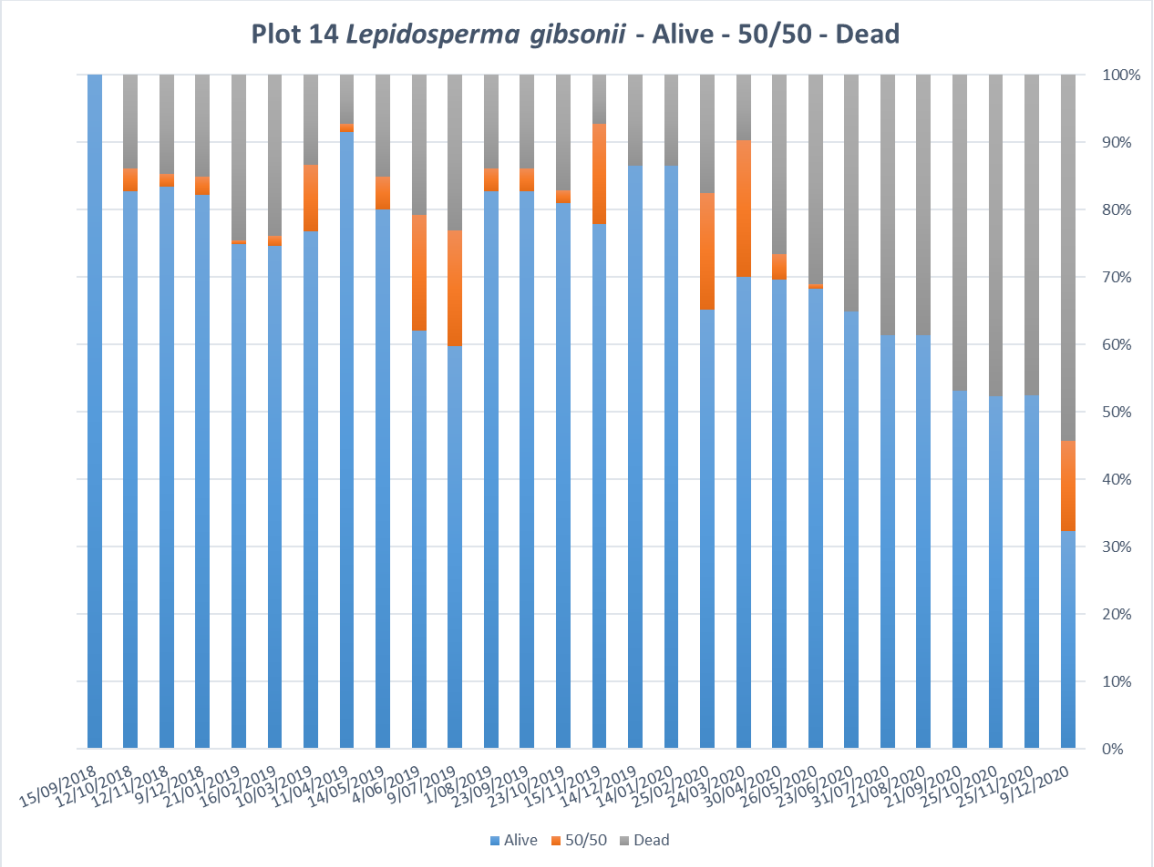



**Figure 20:** Plant survival of *Lepidosperma gibsonii* at Plot 14

## Growth

The average growth per plant was approximately 23.5cm over the 2020 reporting period (Table 10). The majority of plant growth (93%) was positive ranged from 1-40cm (Figure 21).

Approximately 65% of plants showed expansions in basal diameter widths of between 1-4cm over the 2020 reporting period (Table 11). In addition, a significant proportion (23%) of plants showed either zero growth, or a reduction in basal diameter width (Figure 22).

**Table 11** Growth in height of Lepidosperma gibsonii at Plot 14 from 2018-2020

| | Growth 2018 – 2019 (cm) | Growth 2019 – 2020 (cm) | Height (cm) Oct 2019 | Height (cm) Oct 2020 |
|---|---|---|---|---|
| **Average** | 19.6 (+/- 10.6) | 23.5 (+/- 11.2) | 29.7 | 33.5 |
| **Max** | 50.0 | 60.0 | 60.0 | 70 |
| **Min** | 0.0 | 0 | 10.0 | 10 |

**Table 12** Growth in basal diameter of Lepidosperma gibsonii at Plot 14 from 2018 – 2020

| | Basal Diameter (cm) 2018 | Growth 2018-2019 (cm) | Growth 2019-2020 (cm) | Basal Diameter (cm) Dec 2019 | Basal Diameter (cm) Dec 2020 |
|---|---|---|---|---|---|
| **Average** | 3.0 | 1.5 (+/- 1.4) | 2.0 (+/-2.1) | 4.4 | 4.8 |
| **Max** | 6.0 | 7.0 | 13 | 10.0 | 16 |
| **Min** | 1.0 | 0.0 | 0 | 1.0 | 1 |

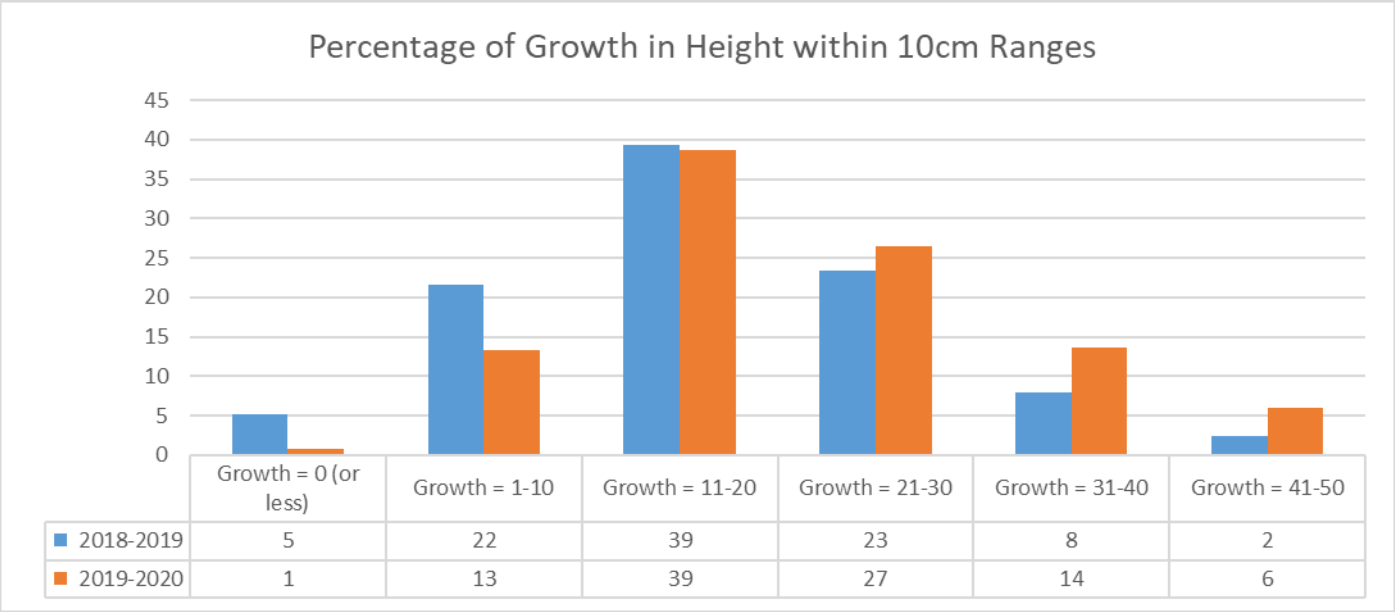



**Figure 21** Percentage change in height growth within 10cm ranges for Plot 14

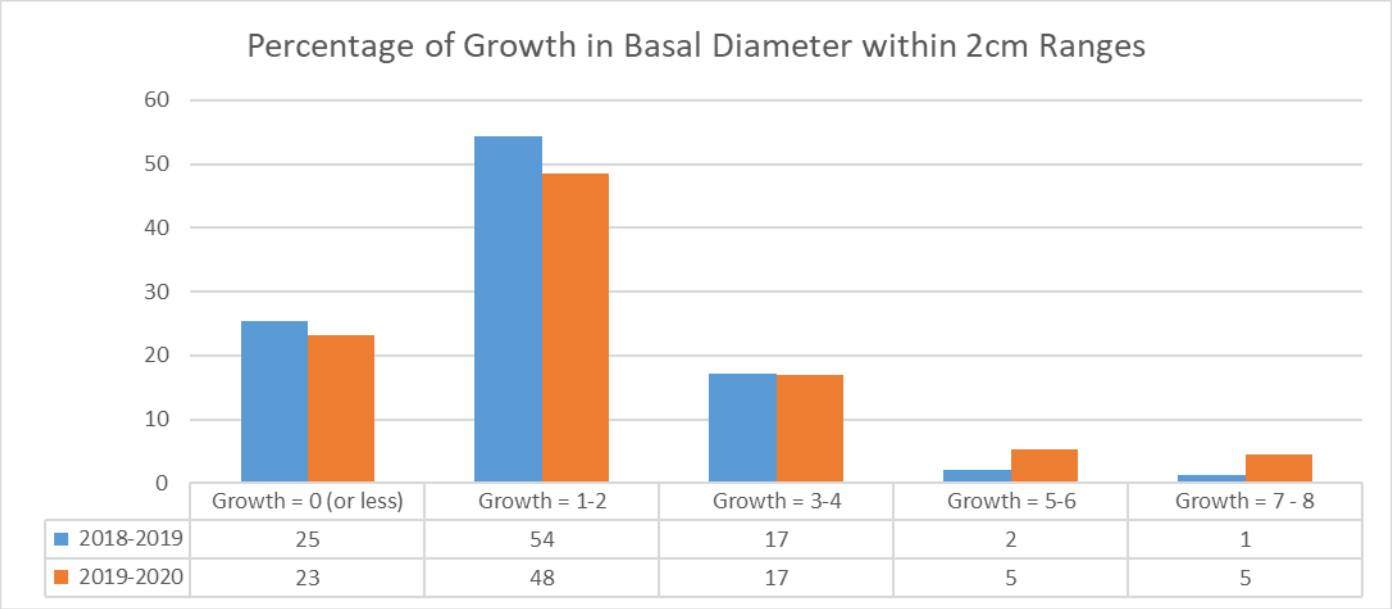



**Figure 22** Percentage of growth in basal diameter within 2cm ranges for Plot 14

## Flowering

Most plants (71%) were recorded as flowering during the reporting period.

# 9. DISCUSSION

## 9.1 Darwinia masonii

In comparison to success criteria, plot IH1WRL(wet) met both the short and medium term criteria for survival as the rate of survival was greater than 70% and more than 200 plants were recorded alive in the plot.

For the survival rate success criteria (>70%), plots 14 and 17 were just below the target (64% and 65% respectively). The other three plots ranged from 37% to 44% survival.

For the total plants per plot success criteria (>200 plants/plot), all plots achieved this target, accept plot 6 and plot IH1WRL(dry). Table 12 summarises the results across all plots.

The plot that returned the highest survival rate was Plot IHWRL(wet) with a 90% survival rate from the 297 plants established in this plot. The lowest survival rate was Plot IHWRL(dry) with a 37% survival rate from the 316 plants established in this plot.

In regards to growth over the reporting period, Plot 14 returned the highest average growth of 34cm and Plot 4 returned the lowest average growth of 13cm, since the plots and any subsequent infill plants were established.

Overall, when compared to 2019, there was a decrease in the flowering rates at all plots. The 2019 combined average for flowering rates was 72%, the combined average for all plots decreased to 49% in 2020. The plot that recorded the highest flowering rate was Plot 17 with 78% of the 560 alive plants producing flowers. The plot that recorded the lowest flowering rate was Plot 16, with only 7% of the 242 alive plants producing flowers.

As mentioned above in section 6.0, weekly irrigation of all plots ceased in winter 2020. This change was made due to the site approaching closure and the reverse osmosis desalination plant which generates potable water scheduled to be decommissioned. From a review of the annual data set, it appears that lack of irrigation has caused a decline in total numbers for some plots and had a reduced effect on other plots. For instance, plot 6 which is located on a loam floodplain site, south of Iron Hill, has seen an overall reduction from 92% survival in 2019 down to 41% survival in 2020. Whereas, plot 17 which is located on a rocky ridge to the north of Iron Hill, has seen a reduction from 91% survival to 65% survival in 2020.

The new data presented this year is in regards to two plots established at the lower batter on the southern side of the Iron Hill waste rock landform. At this location, 297 plants were established with irrigation using the same technique as all other plots. In addition, 316 plants were established without irrigation.

For the non-irrigated plot (IH1WRL-dry) survival gradually decreased from 90% down to stabilising near 40% within 9 months of the seedlings being established. This result was expected and is encouraging, given the translocation plot is established on the southern face of a waste rock landform soil profile and was never irrigated. As illustrated on the cover of this report, the seedlings that remain in plot IH1WRL-dry are tall, strong, healthy individuals, with 50% generating flowers.

With regards to the irrigated plot (IH1WRL-wet) 90% survival was the highest of all plots in 2020. This result is encouraging, given that the plot only received irrigation for the first 12 months, then irrigation was switched off in mid-2020. It appears that a combination of suitable waste rock soil profile and a southern aspect at plot IH1WRL is generating encouraging results.

In mid-late 2020, the presence of viable seed in translocation plots was compared to naturally occurring populations by MBS Environmental through a pilot and phase II study. The results of this work are attached as Appendix A. The key finding from this research are reproduced below:

- *Results from translocation plot 4 (established in 2007) and plot 17 (established in 2017) indicate that the rate of seed fill and number of fruits produced by translocated D. masonii may increase with time and maturity of the occupants within translocation populations. The first two surveys indicated that,*

*after ten years or less, a translocated population can produce abundant seed, which are dispersed by native insects and which have a fill rate (in the soil) consistent with (or in excess of) a natural population. These findings indicate a strong possibility that translocated populations can become self-sustaining by producing a potentially viable soil seedbank, as borne out by the observations of active recruitment in and around plot 4.*

- *Based on results from plot 17, three years appears insufficient for a translocation population to become potentially self-sustaining through soil seedbank recruitment. However, evidence shows that seedbank is accumulating in soils.*
- *Seed foraging by ants is likely a key driver in the abundance and distribution of viable seed in the soil seedbank of D. masonii. Therefore, fill rates of fruit harvested directly from plants are not considered reliable indicators for the fill rates of fruit found in the soil seedbank.*

At the end of the 2020 reporting period, a total of 2134 seedlings were surviving across all the translocation plots. MGM is obliged to offset 1321 seedlings taken in the establishment of the project. Even though the current quantity of alive seedlings at the translocation plots represents 162% of the offset target, MGM propose to establish a further 1000 seedlings from nursery stock at the IHWRL plot. These additional seedlings will also be irrigated for the first 12 months to increase the likelihood of survival. The irrigation water will be sourced from the potable supply in Perenjori.

**Table 13**: Summary results for all *Darwinia masonii* plots in 2020

| Plot # | Hill | Survival | Total Planted | % Survival | Average Growth in Height (cm/yr) | Flowering Rate % |
|---|---|---|---|---|---|---|
| **4** | North of Iron Hill East | 312 | 578 | 54 | 13 | 44 |
| **6** | South of Iron Hill South | 131 | 316 | 41 | 30 | 28 |
| **14** | Iron Hill East | 504 | 792 | 64 | 31 | 76 |
| **16** | Iron Hill Middle | 242 | 547 | 44 | 34 | 7 |
| **17** | Iron Hill Middle | 560 | 863 | 65 | 15 | 78 |
| **IH1WRL Wet** | Iron Hill Deposits Waste Dump (irrigated) | 268 | 297 | 90 | 20 | 63 |
| **IH1WRL Dry** | Iron Hill Deposits Waste Dump (not irrigated) | 117 | 316 | 37 | 21 | 50 |
| **23*** | North of Extension Hill South | n/a | 309 | n/a | n/a | n/a |
| **Total** | | **2,134** | **4,018** | **53** | **23** | **49** |

(Note:*Plot 23 was not monitored in 2020.)

## 9.2 Lepidosperma gibsonii

In comparison to success criteria, plot 11 met the short term criteria for survival as the rate of survival was greater than 50% and more than 200 plants were recorded alive in each plot. However, plot 14 did not meet these short term criteria targets. Table 13 summarises the results across both plots.

The plot that returned the highest survival rate was Plot 11 with a 73% survival rate from the 2385 plants established in this plot initially in July 2017. Plot 14 returned a lower survival rate with 32% of the 576 plants recorded as alive in December 2020. A further 14% of the plants in plot 14 were classified as 50/50. Whether these 77 individuals have actually died, or temporarily senesced, will be confirmed during the winter 2021 plant health assessments.

In regards to growth of the plants over the current reporting period, Plot 14 returned the highest growth rate at 24 cm / year in average height. In regards to growth in basal diameter (girth) of the plots over the reporting period, both plots recorded a combined average of 2cm/year.

For 2020, flowering rates at both plots were recorded and showed positive results with a combined average of 76% of the alive plants producing flowers across both plots.

Overall, it is apparent that the plants in plot 11 are performing well against the criteria in 2020. However, the plants in plot 14, appear to have suffered following cessation of regular irrigation in mid-2020.

**Table 14** Summary results for all *Lepidosperma gibsonii* plots

| Plot # | Survival | Total Planted | % Survival | Average Growth in Height (cm/yr) | Average Basal Dia. Growth (cm/yr) | Flowering Rate % |
|---|---|---|---|---|---|---|
| **11** | 1,738 | 2,385 | 73 | 15 | 1.9 | 82 |
| **14** | 186 | 576 | 32 | 24 | 2.0 | 71 |
| **Total** | **1,924** | **2,961** | **65** | **19.5** | **2.0** | **76** |

# 10. REFERENCES

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# APPENDIX A

## *D.masonii Soil Seedbank Assessment Pilot Study and Phase II*

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# MEMORANDUM

| | | | |
|---|---|---|---|
| Attention: | Troy Collie | From: | Arielle Fontaine |
| Company | Mount Gibson Mining Limited | Date: | 11 March 2021 |
| Subject: | *D. masonii* Soil Seedbank Assessment Pilot Study and Phase II | Project: | Extension Hill and Iron Hill Operation |

## 1. INTRODUCTION

Mount Gibson Mining Limited (MGM) operates the Extension Hill and Iron Hill Operation (the project) located approximately 350 km north east of Perth, in the Midwest region of Western Australia. *Darwinia masonii*, a Threatened flora species listed as Critically Endangered under the *Biodiversity Conservation Act 2016* and Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*, occurs in the project area and is subject to a number of approval conditions linked to the project.

MGM commenced translocations of *D. masonii* in 2016[1] as a direct offset for plants taken to support mining activities for the Iron Hill Hematite Project. Completion criteria for plants at the translocated plots, which were approved by the Department of Biodiversity, Conservation and Attractions (DBCA) and the Department of Water and Environmental Regulation (DWER), include:

1. Establishment of at least 1,327 *D. masonii* individuals, to be of similar health rating to natural populations as determined by the relevant Flora and Vegetation Management and Monitoring Plan. MBS Environmental (MBS) understands that MGM have achieved this completion criteria.
2. Flower production, seed set and seed viability for translocated individuals at rates equivalent to naturally occurring populations for at least two consecutive years. MBS understands that MGM can demonstrate flower production and seed set but need yet to demonstrate seed viability.
3. Presence of viable seeds in soils at translocation plots with germination rates equivalent to naturally occurring populations.

MGM approached MBS in April 2020 with the intent to undertake a phased study to determine whether the translocated populations of *D. masonii* established at their Extension Hill and Iron Hill Operation are potentially self-sustaining through seedbank recruitment (Item 3 above). This memorandum presents the findings on phase I (the initial 'pilot study' phase) and phase II of the study (which included the long-term established plot 4).

The key objectives of phase I and phase II of the soil seedbank assessment study were to:

- Determine what amounts of viable seed are present in the soil seedbank at translocation sites and sites representing undisturbed *D. masonii* habitat (natural sites).
- Compare results from the translocation sites and natural sites to rate the relative performance of the translocation sites.
- Compare results from the translocation sites to investigate the influence of site maturity on the relative performance of the site.

[1] Translocation plots were established prior to 2016 for research purposes through a DPAW approval.

# 2. METHODS

## 2.1 SAMPLING STRATEGY AND FIELD METHODS

A sampling strategy was developed through discussion with Kings Park Science (BGPA/DBCA) and MGM. Based on estimates of plant density, seed production and retention in the seedbank, the sampling design was refined to 14 samples per plot (0.5 x 0.5 m quadrats to a minimum depth of 0.02 m).

Translocation plot 17 and natural site IHM3 were selected by MGM for the pilot study (Figure 1). A sub-plot was selected within each site, each being of similar size (~0.07 ha) to ensure consistent area coverage and sampling density between the natural and translocation sites. Translocation plot 4 was selected by MGM for phase II of the study. A sub-plot was selected within plot 4. This consisted of the BGPA translocation plot installed in 2007 (over twelve years old) which covers an area of approximately 0.02 ha.

MBS personnel conducted the sampling and survey works for the pilot study between 30 June and 2 July 2020, as well as for phase II of the study between 17 and 19 November 2020 at the Extension Hill and Iron Hill Operation. These works were undertaken by Stephanie Stack, Arielle Fontaine and Dane Vincent (Environmental Scientists and Graduate Environmental Scientist, respectively) under the supervision of Troy Collie (MGM)[2]. Fourteen quadrats were placed within each plot, each being within one metre of a mature *D. masonii* individual but otherwise randomly located (Figure 2, Figure 3 and Figure 4).

Soil within each quadrat was excavated to a minimum depth of 0.02 m and sieved to remove gravel and stones (>6.7 mm). Elements of the sampling process are shown in Figure 5. Samples were placed in calico bags and delivered to Kings Park Science on return to Perth.

Ants are suspected to forage for *D. masonii* seed and to stockpile them adjacent to or within nests. Since this may significantly affect the distribution of seed in the soil seedbank, the plots were surveyed for ant nests. One active nest was located within the natural site (IHM3) during the pilot study and one active nest was located within plot 4 during phase II of the study. A soil sample was obtained from each nest (plot IHM3 Ant 1, Figure 6; plot 4 Ant 1, Figure 7).

The plots were also surveyed for the presence of recent seedlings. Individuals were considered seedlings if they were less than 30 cm tall and showed no evidence of flowering.

For each quadrat, the following information was recorded:

- Percentage cover (soil, bare rock and leaf litter).
- Maximum depth of litter.
- Maximum depth of soil sampled.
- Distance to stem and height of the closest mature individual.
- Number of mature *D. masonii* individuals within a two-metre radius.
- Presence of ant activity.

[2] Soil and seed were collected under an *Authorisation to Take or Disturb Threatened Species* (TFL 2-2021), held by Troy Collie for Mount Gibson Iron Limited.

Scale: 1:29000
Original Size: A4
Air Photo Date: Oct 2019
Grid: Australia MGA94 (50)
0 1 km

Mount Gibson Mining Ltd
Extension Hill and
Iron Hill Operation

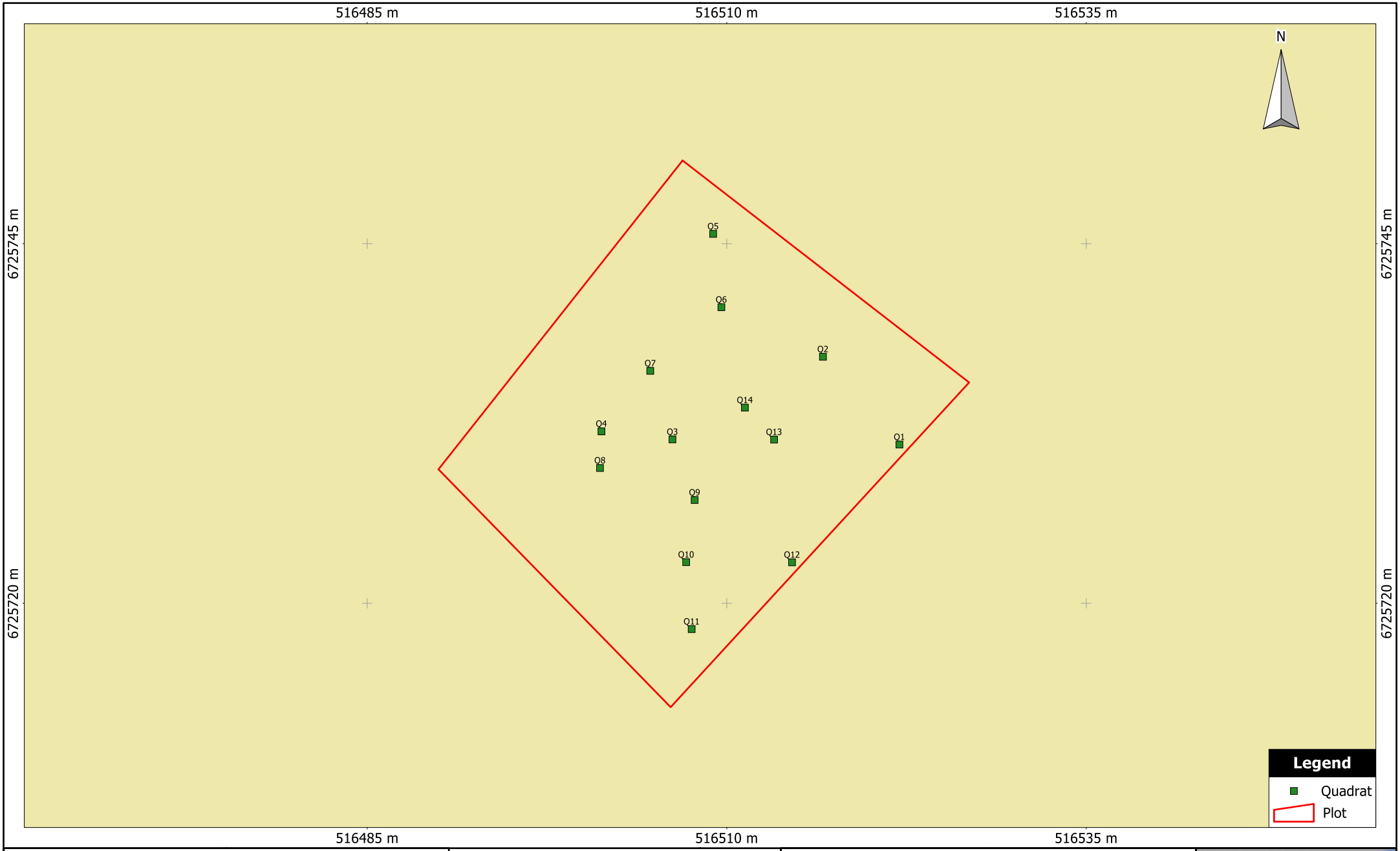
**Figure 1**

**Survey Plot Locations**

Martinick Bosch Sell Pty Ltd
4 Cook St
West Perth WA 6005
Australia
t: +61 8 9226 3166
info@mbsenvironmental.com.au
www.mbsenvironmental.com.au

MBS ENVIRONMENTAL

W:\Mount Gibson\Extension Hill\2020 D Masonii Translocation Seedbank Study\GIS\D. masonii seedbank assessment study.map 11/02/2021 F1 - Plot Locations




Scale: 1:340
Original Size: A4
Grid: MGA94(50)

0 10 m

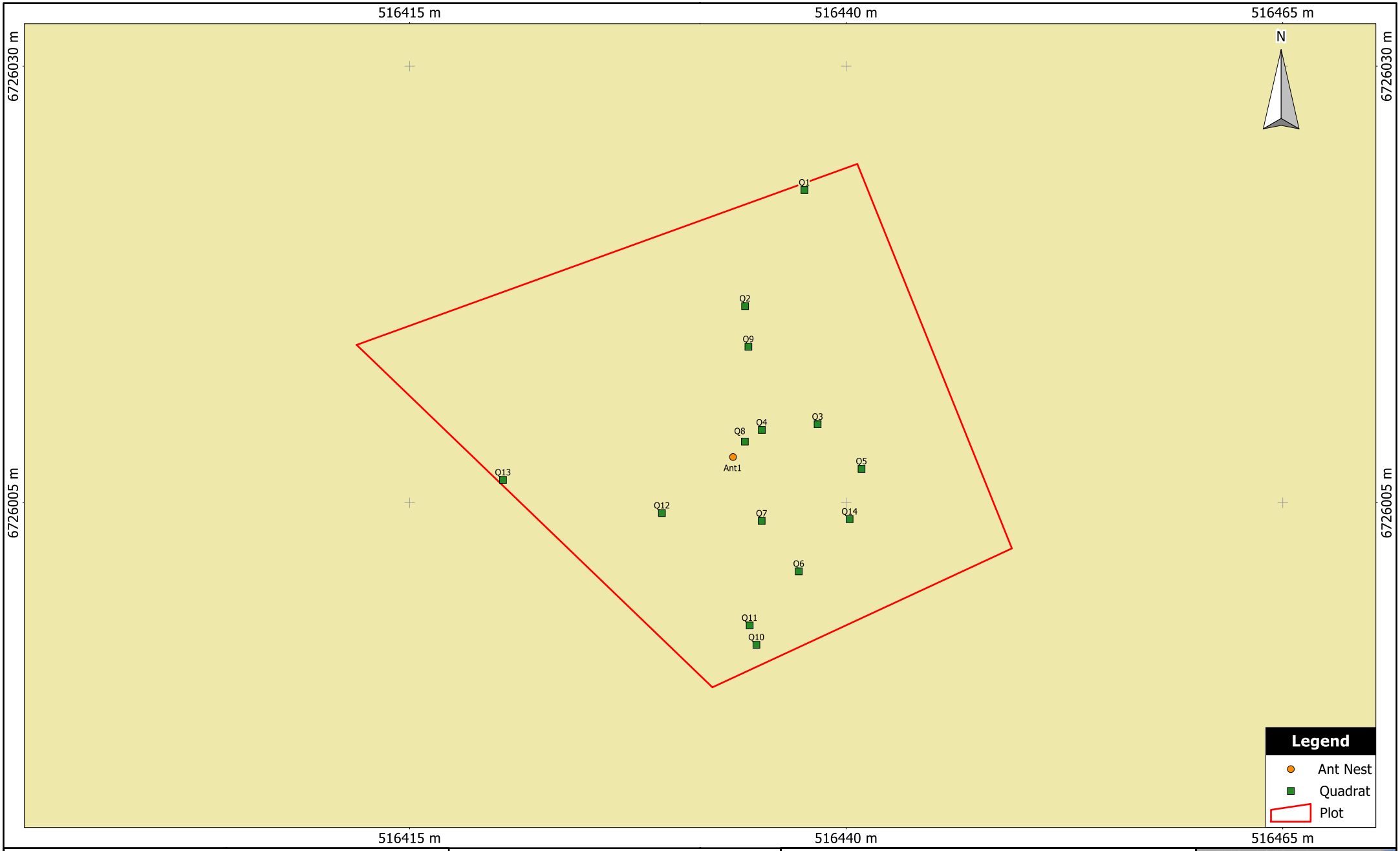
Mount Gibson Mining Ltd
Extension Hill and Iron Hill Operation

**Figure 2**

**Plot 17 Quadrat Locations**

Martinick Bosch Sell Pty Ltd
4 Cook St West Perth WA 6005
Australia
t:+61 8 9226 3166
info@mbsenvironmental.com.au
www.mbsenvironmental.com.au

W:\Mount Gibson\Extension Hill\2020 D Masonii Translocation Seedbank Study\GIS\D. masonii seedbank assessment study.map 11/02/2021 F2 - Plot 17 Quadrat Locations




Scale: 1:280
Original Size: A4
Grid: MGA94(50)

0 10 m

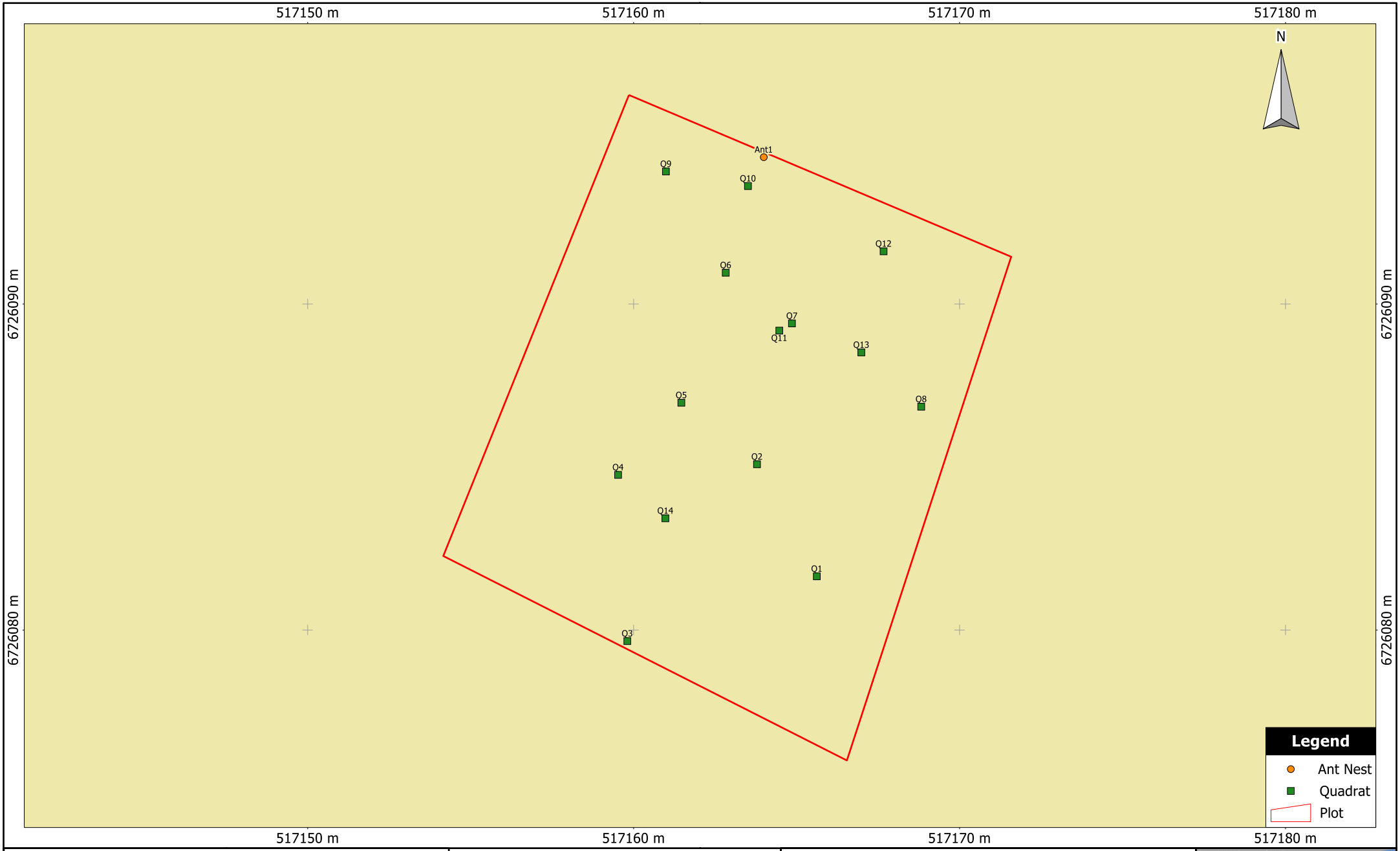
Mount Gibson Mining Ltd
Extension Hill and Iron Hill Operation

**Figure 3**

**Plot IHM3 Quadrat Locations**

Martinick Bosch Sell Pty Ltd
4 Cook St West Perth WA 6005
Australia
t:+61 8 9226 3166
info@mbsenvironmental.com.au
www.mbsenvironmental.com.au

W:\Mount Gibson\Extension Hill\2020 D Masonii Translocation Seedbank Study\GIS\D. masonii seedbank assessment study.map 11/02/2021 F3 - Plot IHM3 Quadrat Locations




Scale: 1:150
Original Size: A4
Grid: MGA94(50)

0 5 m

Mount Gibson Mining Ltd
Extension Hill and Iron Hill Operation

**Figure 4**

**Plot 4 Quadrat Locations**

Martinick Bosch Sell Pty Ltd
4 Cook St West Perth WA 6005
Australia
t:+61 8 9226 3166
info@mbsenvironmental.com.au
www.mbsenvironmental.com.au

W:\Mount Gibson\Extension Hill\2020 D Masonii Translocation Seedbank Study\GIS\D. masonii seedbank assessment study.map 11/02/2021 F4 - Plot 4 Quadrat Locations

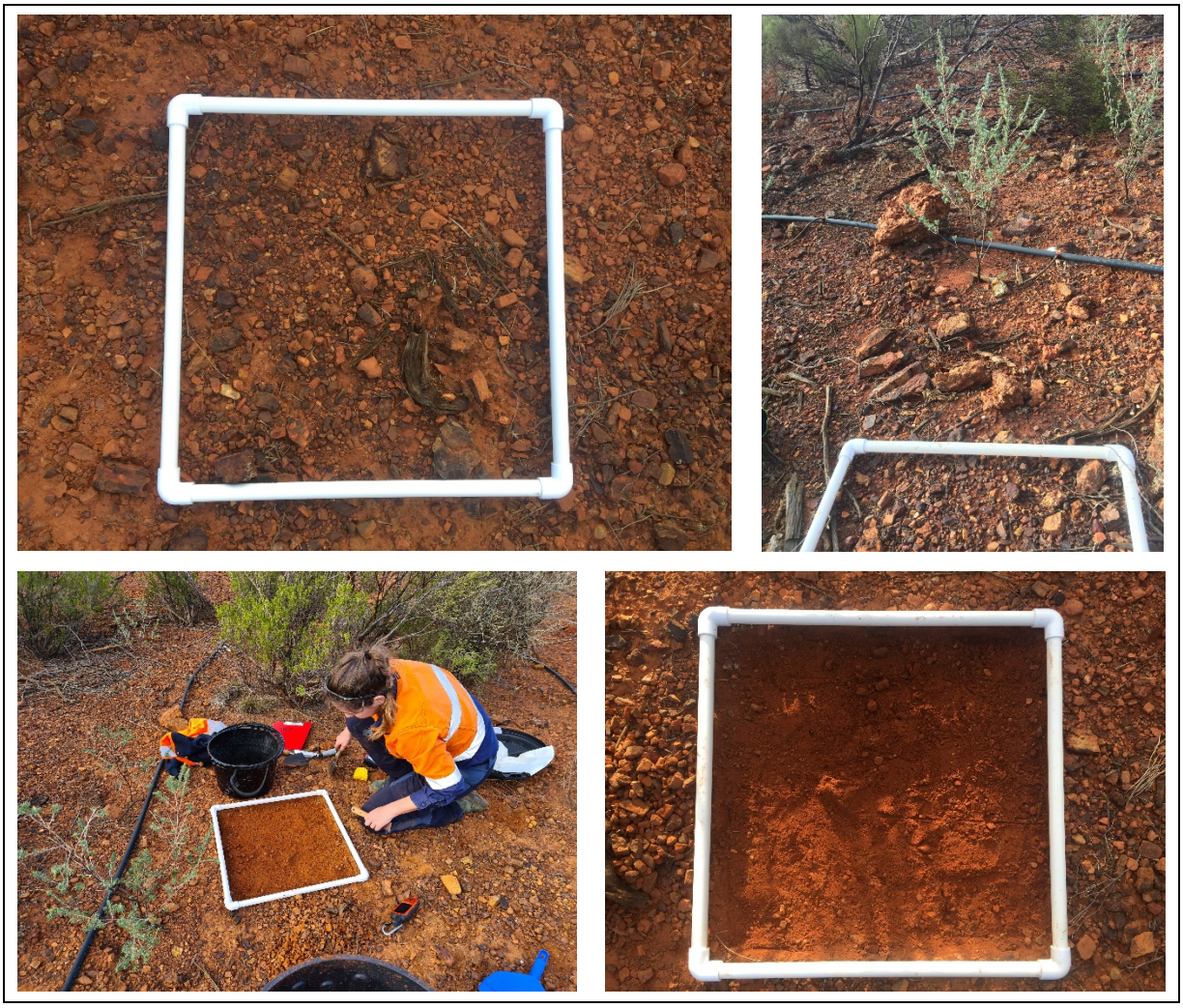


**Figure 5: Quadrats Sampled During the Soil Seedbank Assessment Pilot Study**

*White circles show scattered refuse pile containing D. masonii fruit.*

**Figure 6: Ant Nest Sampled in Plot IHM3**

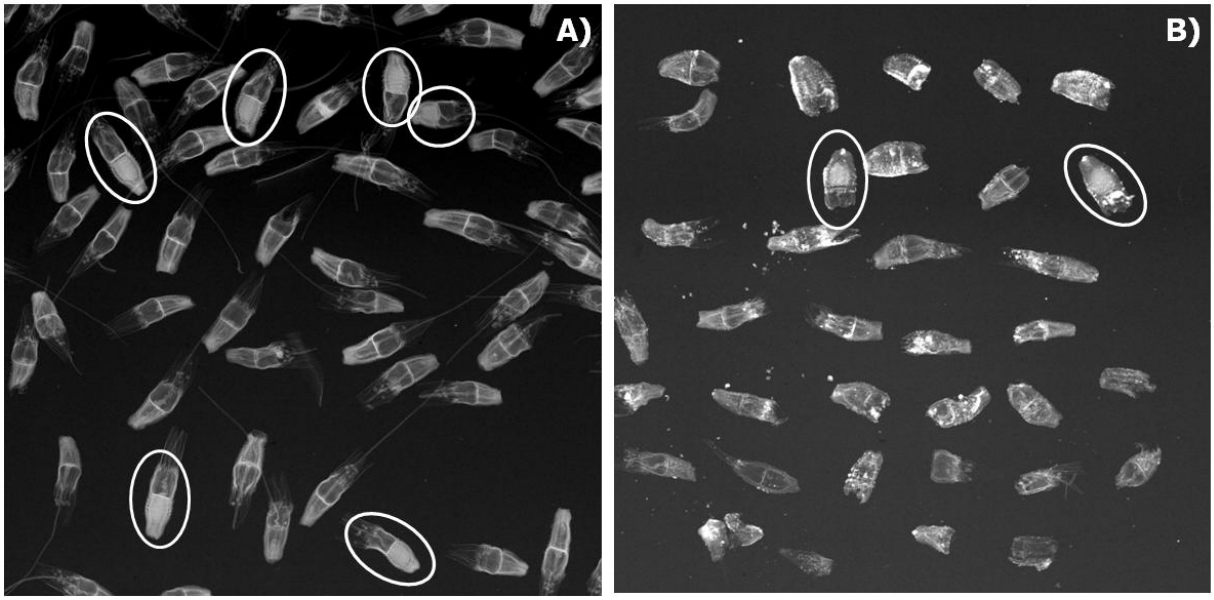
*White circle shows apparent main nest entrance where ants were observed carrying D. masonii fruit. D. masonii fruits were observed scattered around the nest entrance.*

**Figure 7: Ant Nest Sampled in Plot 4**

## 2.2 LABORATORY ANALYSIS

The laboratory component of this study was undertaken by Kings Park Science (DBCA 2021; DBCA 2020). The key aspects of this work were:

- Drying and sieving soil samples to isolate soil fractions containing *D. masonii* fruits. Samples were dried in a warm glasshouse for several days after which they were sieved to isolate fruits (sieve apertures 2.36 mm and 1.18 mm).
- Isolating the fruits in the oversize (>2.36 mm) soil fraction and the sieved (<2.36 mm and >1.18 mm) soil fraction using optical microscopy. The undersize (<1.18 mm) soil fraction was randomly examined to verify that it contained no *D. masonii* fruits.
- Counting isolated fruits and recording their size and condition. Fruits were graded based on size (e.g. small or large fruit) and whether they were in any way damaged (e.g. fragmented).
- X-ray screening the isolated fruits to determine seed fill. All fruits, including any fragments or broken/split fruit found in each sample, were x-rayed (Faxitron specimen X-ray) to assess seed fill as illustrated in Figure 8.




*Circles indicate fruit with filled seed*

**Figure 8: X-rays of Fruit Collected Directly From Plants (A) and Isolated in Soil (B)**

# 3. RESULTS AND DISCUSSIONS

Key laboratory results are summarised in Table 1 and discussed below. Complete field and laboratory data are provided in Appendix 1.

## 3.1 KEY FINDINGS FROM THE PILOT STUDY

The key findings were:

- The translocation plot (plot 17) soils contained fewer fruit per volume of soil compared with soils from the natural population (IHM3) as shown in Chart 1. Soils in the translocation plot contained 924 ± 396 fruits/$m^3$ (mean ± standard error of the mean, SEM) compared with 9,065 ± 3,357 fruits/$m^3$ in the natural population plot.

- Soils in quadrats from both plots contained highly variable amounts of fruits, ranging between zero and 42,800 fruits/m$^3$, although the translocation plot contained a larger proportion of quadrats with no fruits (4/14) than the natural population plot (2/14).
- The translocation plot yielded a single fruit with filled seed out of the 87 fruits collected, equating to a fill rate of 4.2% for a single quadrat. Fruits from the natural population plot contained 15 filled seed from six quadrats (out of 444 fruits) with a fill rate of between 1.9% and 12.5% between those six quadrats (average 5.4%). Whilst the average fill rate in quadrats where filled seed were located was similar, substantially more filled seed were isolated from the natural population plot and filled seed were more evenly distributed within that survey plot. Based on the total number of fruits and filled seed isolated, plot seed fill rates were 1.1% (1 of 87 fruits) for the translocation plot and 3.4% (15 of 444 fruits) for the natural population plot.
- Long-term monitoring (2007 - 2018) of fill rate in infructescences collected directly from plants in natural populations indicate that between 6 and 39% of fruits produced (mean of 21%) contain filled seed (MGM 2020a). The comparatively low fill rates observed in the seedbank suggest that seed predation, together with physical processes in the soil, may be a significant influencer of seedbank abundance. This hypothesis is corroborated by the relatively high proportion of damaged fruit identified at both the translocation and natural plots (means of 38% and 30% respectively).
- Fruits collected from the refuse piles (Figure 6) had a fill rate approximately three times higher (15%) than that of the fruit in the soil seedbank (IHM3), a preliminary indicator that ants may selectively forage for fruits containing filled seed.
- The proportion of fruit collected from the translocation plot that were rated as 'small' (mean of 49%) was higher than in the natural population plot (mean of 16%). Assuming that larger fruit are more likely to be filled, this may be a contributing factor to the comparatively low number of filled fruits found in the translocation plot.
- No seedlings were found at either survey plot. The germination and emergence of *D. masonii* is complicated by the requirement for dormancy break and germination triggers (e.g. smoke). Previous research suggests that significant *D. masonii* recruitment events are supported by a combination of adequate dormancy break, fire and subsequently favourable rainfall (BGPA 2010). Since it is not practical (or permissible) to undertake controlled burns at this stage, demonstrating the presence of a potentially viable seedbank is considered the optimal approach for the purposes of determining whether the completion criteria are met.

## 3.2 KEY FINDINGS FROM PHASE II

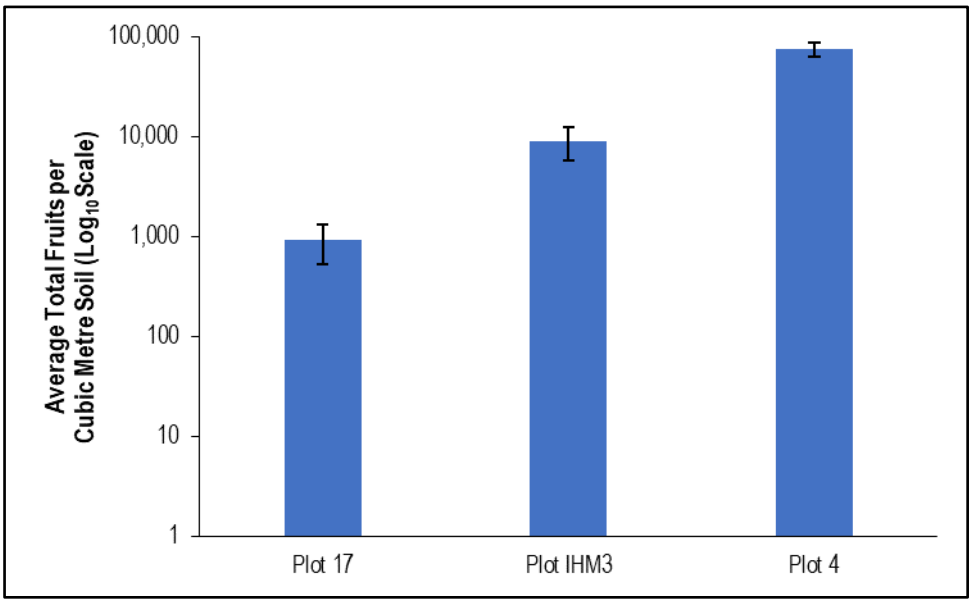
The key findings were:

- Translocation plot 4 soils contained 75,162 ± 12,797 fruits/m$^3$ (mean ± SEM; Chart 1), which is substantially higher than soils from both translocation plot 17 (924 ± 396 fruits/m$^3$) and the natural population IHM3 (9,065 ± 3,357 fruits/m$^3$). It is important to note the potential for seasonal influence given that samples were collected from plot 4 in November, which coincided with the maturation and fruit fall from *D. masonii* (versus pilot study samples collected in June-July). The 2020 season's fruit present on the soil surface could not be effectively separated from older fruit present in the soil seedbank during the laboratory component of this study. Hence these recently fallen fruit may have inflated the soil seedbank measures for plot 4 (DBCA 2021).
- As observed in the pilot study, soils in quadrats from translocation plot 4 contained highly variable amounts of fruits, ranging between 8,000 and 200,235 fruits/m$^3$.
- Fruits from translocation plot 4 contained 164 filled seed (out of 4,600 fruits) with samples from all 14 quadrats containing filled seed. Fill rates were between 1.3% and 10% (average of 4.3 ± 0.7%), which is consistent with results obtained from the natural population IHM3 (2.7 ± 1.1%) (DBCA 2021; DBCA 2020).
- The number of mature plants within a two-metre radius of the quadrats was substantially higher at translocation plot 4 (15) compared with both the natural population site IHM3 (4) and the younger

translocation plot 17 (7). The seedbank abundance (fruits/m$^3$) data were density normalised[3] to assess whether the density of plants at each site significantly affects overall seedbank abundance between plots. Compensating for plant density, average normalised seedbank abundance was still greater at plot 4 (5,942 ± 1,197 fruits/m$^3$) compared with the natural population site, IHM3 (3,177 ± 1,897 fruits/m$^3$) and plot 17 (125 ± 52 fruits/m$^3$) (Chart 2).

- The proportion of damaged fruit identified at translocation plot 4 (24%) was relatively high, and of a similar magnitude to that recorded at the younger translocation plot (38%) and the natural population site (30%). As observed for the pilot study, these results suggested that seed predation may be a significant influencer of seedbank abundance.
- The proportion of fruit from plot 4 rated as 'small' (mean 38%) was intermediate between the natural population plot (16%) and the younger translocation plants, plot 17 (49%). Following on from comments on the pilot study, these results may reflect the maturity of the individuals at plot 4, which was established ten years prior to plot 17 (MGM 2020b). This hypothesis is supported by average heights of the closest mature individual to each soil quadrat. The average for translocation plot 4 was 117 cm, which was substantially higher than that of translocation plot 17 (64 cm) but slightly lower than that of the natural population plot (128 cm).
- Several ants were observed carrying *D. masonii* fruit within quadrats and in proximity to the ant nest sampled at translocation plot 4 (Figure 9). This indicates that ants are likely one of the primary drivers of *D. masonii* fruit dispersal across the landscape, confirming observations made at plot IHM3 and previous research undertaken on site by Kings Park Science and the University of Western Australia (Ruoss 2013). The nest at plot 4 contained substantially more fruit (306) than the nest at the natural population site, IHM3 (20), which likely reflects the coincidence of the second survey with seasonal fruit fall. Also, the two nests were sampled differently, whereby distinct refuse piles were observed and sampled at plot IHM3 compared with a broader sample of fruit present in the vicinity of the nest in plot 4.
- Whilst fruits collected from the nest in plot 4 had a substantially higher fill rate (8%) than the average for the soil seedbank (4.3 ± 0.7%), the fill rate was within the range for the 14 soil quadrats (1.3 - 10%) at plot 4. This contrasts with the interpretation of results from the pilot study, which indicated that ants selectively forage for fruits containing filled seed. An alternative hypothesis is that ants selectively forage for larger fruit, potentially providing greater food source, rather than just the seeds within the fruit. The proportion of fruit rated as 'small' was lower in nests versus the soil seedbank average at both plot IHM3 (5% in nest vs. 16 ± 4% in seedbank) and plot 4 (12% in nest vs. 38 ± 3% in seedbank).
- One seedling was observed at translocation plot 4, measuring 19 cm in height (Figure 10) and with no known history of flowering (pers. com. B. O'Grady).

[3] Fruit density per cubic metre soil divided by number of mature *D. masonii* within a two metre radius of each quadrat.




*Note: Error bars represent standard error of the mean.*

**Chart 1: Mean Total Number of *D. masonii* Fruits per Cubic Metre Soil ($Log_{10}$ Scale)**

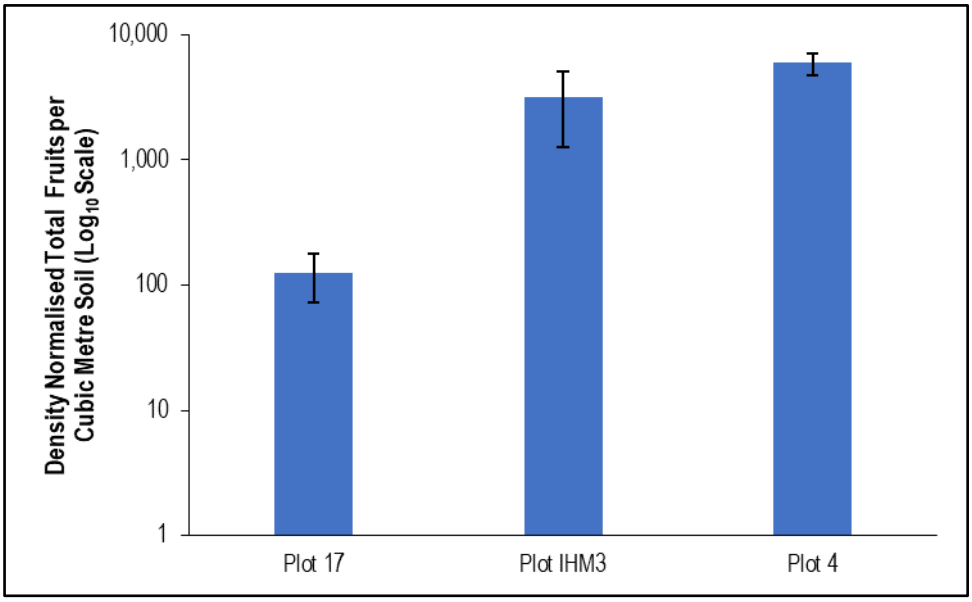



**Chart 2: Mean Total Number of *D. masonii* Fruits per Cubic Metre Soil Normalised to Plant Density ($Log_{10}$ Scale)**

*Ant observed carrying D. masonii fruit inside quadrat.*

*Ant observed carrying D. masonii fruit to nest entrance.*

**Figure 9: Ant Activity Observed in Plot 4**

**Figure 10: Seedling Observed in Plot 4**

**Table 1: Summary of Fruit Quantity, Size, Condition and Seed Fill**

| Plot | Quadrat | Date Sampled | Quantity and Condition of Fruit (per m³ soil) | | | | | | Seed Fill | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Large Whole Fruit | Small Whole Fruit | Damaged Fruit | Total Fruit | % Fruit Damaged | % Small Fruit | Filled Seed (per m³ soil) | % Seed Filled |
| Plot 17 | Q1 | 30-Jun-20 | 1,867 | 1,733 | 1,733 | 5,333 | 33 | 33 | 0 | 0 |
| | Q2 | 30-Jun-20 | 0 | 0 | 133 | 133 | 100 | 0 | 0 | 0 |
| | Q3 | 30-Jun-20 | 133 | 133 | 933 | 1,200 | 78 | 11 | 0 | 0 |
| | Q4 | 30-Jun-20 | 1,333 | 267 | 1,600 | 3,200 | 50 | 8 | 133 | 4.2 |
| | Q5 | 1-Jul-20 | 0 | 200 | 0 | 200 | 0 | 100 | 0 | 0 |
| | Q6 | 1-Jul-20 | 667 | 444 | 222 | 1,333 | 17 | 33 | 0 | 0 |
| | Q7 | 1-Jul-20 | 0 | 0 | 0 | 0 | | | | |
| | Q8 | 1-Jul-20 | 0 | 0 | 0 | 0 | | | | |
| | Q9 | 1-Jul-20 | 0 | 222 | 222 | 444 | 50 | 50 | 0 | 0 |
| | Q10 | 1-Jul-20 | 0 | 211 | 0 | 211 | 0 | 100 | 0 | 0 |
| | Q11 | 1-Jul-20 | 0 | 333 | 333 | 667 | 50 | 50 | 0 | 0 |
| | Q12 | 1-Jul-20 | 0 | 211 | 0 | 211 | 0 | 100 | 0 | 0 |
| | Q13 | 1-Jul-20 | 0 | 0 | 0 | 0 | | | | |
| | Q14 | 1-Jul-20 | 0 | 0 | 0 | 0 | | | | |
| Plot IHM3 | Q1 | 1-Jul-20 | 0 | 0 | 0 | 0 | | | | |
| | Q2 | 1-Jul-20 | 667 | 0 | 0 | 667 | 0 | 0 | 0 | 0 |
| | Q3 | 1-Jul-20 | 471 | 706 | 706 | 1,882 | 38 | 38 | 235 | 12.5 |
| | Q4 | 1-Jul-20 | 12,400 | 15,200 | 15,200 | 42,800 | 36 | 36 | 800 | 1.9 |
| | Q5 | 1-Jul-20 | 941 | 235 | 0 | 1,176 | 0 | 20 | 0 | 0 |
| | Q6 | 1-Jul-20 | 4,000 | 889 | 2,444 | 7,333 | 33 | 12 | 0 | 0 |
| | Q7 | 1-Jul-20 | 8,286 | 2,571 | 3,143 | 14,000 | 22 | 18 | 1,143 | 8.2 |
| | Q8 | 1-Jul-20 | 10,333 | 4,667 | 5,333 | 20,333 | 26 | 23 | 667 | 3.3 |
| | Q9 | 1-Jul-20 | 0 | 0 | 222 | 222 | 100 | 0 | 0 | 0 |
| | Q10 | 1-Jul-20 | 4,889 | 2,667 | 889 | 8,444 | 11 | 32 | 222 | 2.6 |
| | Q11 | 1-Jul-20 | 0 | 0 | 0 | 0 | | | | |
| | Q12 | 1-Jul-20 | 1,200 | 0 | 400 | 1,600 | 25 | 0 | 0 | 0 |
| | Q13 | 1-Jul-20 | 222 | 0 | 222 | 444 | 50 | 0 | 0 | 0 |
| | Q14 | 1-Jul-20 | 18,105 | 4,421 | 5,474 | 28,000 | 20 | 16 | 1,053 | 3.8 |
| Plot 4 | Q1 | 18-Nov-20 | 8,632 | 5,474 | 3,158 | 17,263 | 18 | 32 | 421 | 2.4 |
| | Q2 | 18-Nov-20 | 24,000 | 30,667 | 27,733 | 82,400 | 34 | 37 | 4,533 | 5.5 |
| | Q3 | 18-Nov-20 | 3,333 | 3,111 | 1,556 | 8,000 | 19 | 39 | 444 | 5.6 |
| | Q4 | 18-Nov-20 | 12,235 | 17,882 | 8,471 | 38,588 | 22 | 46 | 2,118 | 5.5 |
| | Q5 | 18-Nov-20 | 93,412 | 48,941 | 57,882 | 200,235 | 29 | 24 | 3,059 | 1.5 |
| | Q6 | 18-Nov-20 | 24,421 | 10,105 | 11,579 | 46,105 | 25 | 22 | 3,789 | 8.2 |
| | Q7 | 18-Nov-20 | 17,412 | 40,000 | 27,294 | 84,706 | 32 | 47 | 1,882 | 2.2 |
| | Q8 | 18-Nov-20 | 11,789 | 13,053 | 7,579 | 32,421 | 23 | 40 | 1,474 | 4.5 |
| | Q9 | 18-Nov-20 | 22,737 | 49,474 | 23,579 | 95,789 | 25 | 52 | 1,263 | 1.3 |
| | Q10 | 18-Nov-20 | 66,444 | 43,778 | 23,778 | 134,000 | 18 | 33 | 4,000 | 3.0 |
| | Q11 | 18-Nov-20 | 22,316 | 39,158 | 14,105 | 75,579 | 19 | 52 | 4,000 | 5.3 |
| | Q12 | 18-Nov-20 | 51,765 | 15,529 | 16,235 | 83,529 | 19 | 19 | 2,824 | 3.4 |
| | Q13 | 18-Nov-20 | 34,588 | 35,529 | 22,118 | 92,235 | 24 | 39 | 1,647 | 1.8 |
| | Q14 | 18-Nov-20 | 18,588 | 27,294 | 15,529 | 61,412 | 25 | 44 | 6,118 | 10.0 |

# 4. KEY STUDY OUTCOMES

The main outcomes of the pilot study and phase II are:

- Results from translocation plot 17 (established in 2017) and plot 4 (established in 2007) indicate that the rate of seed fill and number of fruits produced by translocated *D. masonii* may increase with time and maturity of the occupants within translocation populations. The first two surveys indicated that, after ten years or less, a translocated population can produce abundant fruit, which are dispersed by native insects and which have a fill rate (in the soil) consistent with (or in excess of) a natural population. These findings indicate a strong possibility that translocated populations can become self-sustaining by producing a potentially viable soil seedbank, as borne out by the observations of active recruitment in and around plot 4.
- Based on results from plot 17, three years appears insufficient for a translocation population to become potentially self-sustaining through soil seedbank recruitment. However, evidence shows that seedbank is accumulating in soils.
- Seed foraging by ants, together with physical processes in the soil, are likely key drivers in the abundance and distribution of viable seed in the soil seedbank of *D. masonii*. Therefore, fill rates of fruit harvested directly from plants are not considered reliable indicators for the fill rates of fruit found in the soil seedbank.

# 5. RECOMMENDATIONS FOR FUTURE WORKS

The main outcomes of the surveys undertaken thus far highlight a number of areas which would benefit from further investigation. These include but are not limited to:

- Understanding the influence of seasonal variation on results obtained from translocation plots and natural population sites.
- Understanding the dynamics between fruit fall and incorporation of fruit into the soil seedbank. A first step would be to distinguish between fruit from the soil seedbank and fruit present on the soil surface following seasonal fruit fall. It is assumed that a number of these fallen fruits would eventually be incorporated into the soil seedbank, but a large portion would likely be lost through seed predation or dispersed across the landscape through ant activity.

It is recommended that future sampling works would include the use of a vacuum device to collect surface fruit separately to fruit stored in the soil seedbank. The same technique used during the pilot study and phase II would then be used to sample the soil seedbank. The sampling strategy and analysis methods developed during the pilot study appear to be successful, based on the number of fruits obtained relative to sampling intensity and soil volume. Efficiency gains are likely possible by field-sieving soils using sieve apertures of 6.7 mm and 1.18 mm to remove gravel/stones and fine soil fractions that do not contain *D. masonii* fruit. This would not substantially increase the sampling effort but would reduce laboratory processing time.

Though a seedling was found within translocation plot 4, demonstrating the presence of a potentially viable seedbank is still considered the optimal approach for the purposes of determining whether the completion criteria are met, given the fact that germination and emergence of *D. masonii* is complicated by the requirement for germination triggers (e.g. smoke) and dormancy break.

Given the limited frequency of optimal survey periods (i.e. shortly after seasonal fruit fall), it is recommended that any future studies be expanded to include multiple sites. It is suggested a minimum of three translocated sites and three natural sites be targeted during each subsequent survey effort. This would allow for some replication and provide greater statistical certainty for the findings. It is also recommended that translocation sites with different histories be included in future works (i.e. 5 to 7-year-old translocation sites vs. 3-year-old and 12-year-old sites).

I trust that these findings will help MGM to develop their strategy for ongoing translocation population monitoring and associated research activities for *D. masonii* direct offsets. Please contact me or Kristy Sell if you would like to discuss these findings or future projects.

Yours sincerely
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# APPENDICES

# APPENDIX 1: COMPLETE FIELD AND LABORATORY DATA (PILOT STUDY AND PHASE II)

**Table A1-1: Field Survey Data**

| Plot | Sample ID | Date Sampled | Estimated Percentage Ground Cover | | | Max. Excavation Depth | | Estimated Collected Soil Volume ($m^3$) | Closest Mature *D. Masonii* | | No. Mature *D. masonii* Within 2 m | Ant Activity (Y/N) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Soil (%) | Bare Rock (%) | Litter (%) | Litter (mm) | Soil (cm) | | Distance to Stem (cm) | Height (cm) | | |
| Plot 17 | Q1 | 30-Jun-20 | 100 | 0 | 15 | 6 | 3 | 0.0075 | 24 | 78 | 7 | N |
| | Q2 | 30-Jun-20 | 100 | 0 | 70 | 27 | 3 | 0.0075 | 35 | 42 | 7 | N |
| | Q3 | 30-Jun-20 | 100 | 0 | 75 | 5 | 3 | 0.0075 | 31 | 40 | 7 | N |
| | Q4 | 30-Jun-20 | 100 | 0 | 10 | 3 | 3 | 0.0075 | 34 | 84 | 11 | N |
| | Q5 | 1-Jul-20 | 100 | 0 | 5 | 2 | 2 | 0.005 | 61 | 59 | 7 | N |
| | Q6 | 1-Jul-20 | 90 | 10 | 5 | 35 | 2 | 0.0045 | 43 | 54 | 7 | N |
| | Q7 | 1-Jul-20 | 100 | 0 | 30 | 15 | 2 | 0.005 | 40 | 79 | 6 | N |
| | Q8 | 1-Jul-20 | 95 | 5 | 35 | 20 | 2 | 0.0045 | 23 | 84 | 5 | N |
| | Q9 | 1-Jul-20 | 95 | 5 | 45 | 20 | 2 | 0.0045 | 55 | 57 | 4 | N |
| | Q10 | 1-Jul-20 | 100 | 0 | 20 | 12 | 2 | 0.00475 | 65 | 72 | 5 | N |
| | Q11 | 1-Jul-20 | 60 | 40 | 15 | 10 | 2 | 0.003 | 58 | 34 | 7 | N |
| | Q12 | 1-Jul-20 | 95 | 5 | 15 | 12 | 2 | 0.00475 | 74 | 82 | 6 | N |
| | Q13 | 1-Jul-20 | 95 | 5 | 25 | 8 | 2 | 0.005 | 33 | 62 | 10 | N |
| | Q14 | 1-Jul-20 | 90 | 10 | 80 | 13 | 2 | 0.005 | 51 | 71 | 6 | N |
| Plot IHM3 | Q1 | 1-Jul-20 | 95 | 5 | 10 | 15 | 2 | 0.005 | 52 | 98 | 1 | N |
| | Q2 | 1-Jul-20 | 95 | 5 | 15 | 7 | 2 | 0.0045 | 86 | 153 | 2 | N |
| | Q3 | 1-Jul-20 | 60 | 40 | 20 | 15 | 2 | 0.00425 | 74 | 168 | 4 | N |
| | Q4 | 1-Jul-20 | 50 | 50 | 15 | 5 | 2 | 0.0025 | 43 | 163 | 16 | Ants nest 69 cm from quadrat |
| | Q5 | 1-Jul-20 | 90 | 10 | 30 | 30 | 2 | 0.00425 | 25 | 127 | 2 | N |
| | Q6 | 1-Jul-20 | 100 | 0 | 20 | 16 | 2 | 0.0045 | 27 | 160 | 3 | N |
| | Q7 | 1-Jul-20 | 95 | 5 | 90 | 62 | 2 | 0.0035 | 30 | 120 | 10 | N |
| | Q8 | 1-Jul-20 | 80 | 20 | 85 | 41 | 2 | 0.003 | 33 | 94 | 3 | N |
| | Q9 | 1-Jul-20 | 100 | 0 | 5 | 10 | 2 | 0.0045 | 75 | 152 | 1 | N |
| | Q10 | 1-Jul-20 | 95 | 5 | 15 | 28 | 2 | 0.0045 | 9 | 104 | 9 | N |
| | Q11 | 1-Jul-20 | 90 | 10 | 75 | 45 | 2 | 0.004 | 41 | 141 | 2 | N |
| | Q12 | 1-Jul-20 | 60 | 40 | 20 | 8 | 2 | 0.0025 | 22 | 70 | 4 | N |
| | Q13 | 1-Jul-20 | 90 | 10 | 20 | 19 | 2 | 0.0045 | 58 | 121 | 2 | N |
| | Q14 | 1-Jul-20 | 95 | 5 | 5 | 16 | 2 | 0.00475 | 40 | 123 | 1 | N |
| | Ant1 | 1-Jul-20 | - | - | - | - | 3 | Not determined | 108 | 137 | 5 | Y |
| Plot 4 | Q1 | 18-Nov-20 | 95 | 5 | 5 | 4 | 2 | 95 | 22 | 124 | 20 | Y |
| | Q2 | 18-Nov-20 | 80 | 20 | 10 | 20 | 2 | 75 | 15 | 150 | 20 | Y |
| | Q3 | 18-Nov-20 | 90 | 10 | 15 | 10 | 2 | 90 | 22 | 61 | 15 | Y |
| | Q4 | 18-Nov-20 | 92 | 8 | 10 | 30 | 2 | 85 | 9 | 112 | 15 | Y |
| | Q5 | 18-Nov-20 | 90 | 10 | 60 | 15 | 2 | 85 | 16 | 100 | 17 | Y |
| | Q6 | 18-Nov-20 | 95 | 5 | 40 | 28 | 2 | 95 | 25 | 111 | 12 | Y |
| | Q7 | 18-Nov-20 | 90 | 10 | 5 | 5 | 2 | 85 | 17 | 93 | 14 | N |
| | Q8 | 18-Nov-20 | 95 | 5 | 10 | 18 | 2 | 95 | 14 | 142 | 17 | N |
| | Q9 | 18-Nov-20 | 100 | 0 | 40 | 12 | 2 | 95 | 28 | 128 | 12 | Y |
| | Q10 | 18-Nov-20 | 90 | 10 | 20 | 8 | 2 | 90 | 29 | 112 | 9 | N |
| | Q11 | 18-Nov-20 | 95 | 5 | 50 | 40 | 2 | 95 | 17 | 130 | 16 | N |
| | Q12 | 18-Nov-20 | 85 | 15 | 5 | 20 | 2 | 85 | 37 | 137 | 6 | Y |
| | Q13 | 18-Nov-20 | 90 | 10 | 5 | 20 | 2 | 85 | 17 | 122 | 14 | N |
| | Q14 | 18-Nov-20 | 95 | 5 | 10 | 15 | 2 | 85 | 18 | 113 | 18 | Y |
| | Ant1 | 18-Nov-20 | - | - | - | - | - | - | 36 | 110 | 10 | Y |

**Table A1-2: Field Survey Data**

| Plot | Seedling ID | Date of Survey | Height (cm) | Health Score (based on BGPA scale) | Closest Mature *D. Masonii* | | | | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Distance to Stem (cm) | Height (cm) | Health | Reproductive State | |
| Plot 4 | DM01 | 18-Nov-20 | 19 | 2 | 37 | 150 | 2 | End of flowering | Seedling found within 90 cm of four mature *D. masonii* individuals. |

**Table A1-3: Laboratory Data**

| Plot | Sample ID | Date Sampled | Whole Fruit | | Damaged Fruit | Total No. Fruit | No. Filled Seed |
|---|---|---|---|---|---|---|---|
| | | | Large | Small | | | |
| Plot 17 | Q1 | 30-Jun-20 | 14 | 13 | 13 | 40 | 0 |
| | Q2 | 30-Jun-20 | 0 | 0 | 1 | 1 | 0 |
| | Q3 | 30-Jun-20 | 1 | 1 | 7 | 9 | 0 |
| | Q4 | 30-Jun-20 | 10 | 2 | 12 | 24 | 1 |
| | Q5 | 1-Jul-20 | 0 | 1 | 0 | 1 | 0 |
| | Q6 | 1-Jul-20 | 3 | 2 | 1 | 6 | 0 |
| | Q7 | 1-Jul-20 | 0 | 0 | 0 | 0 | 0 |
| | Q8 | 1-Jul-20 | 0 | 0 | 0 | 0 | 0 |
| | Q9 | 1-Jul-20 | 0 | 1 | 1 | 2 | 0 |
| | Q10 | 1-Jul-20 | 0 | 1 | 0 | 1 | 0 |
| | Q11 | 1-Jul-20 | 0 | 1 | 1 | 2 | 0 |
| | Q12 | 1-Jul-20 | 0 | 1 | 0 | 1 | 0 |
| | Q13 | 1-Jul-20 | 0 | 0 | 0 | 0 | 0 |
| | Q14 | 1-Jul-20 | 0 | 0 | 0 | 0 | 0 |
| Plot IHM3 | Q1 | 1-Jul-20 | 0 | 0 | 0 | 0 | 0 |
| | Q2 | 1-Jul-20 | 3 | 0 | 0 | 3 | 0 |
| | Q3 | 1-Jul-20 | 2 | 3 | 3 | 8 | 1 |
| | Q4 | 1-Jul-20 | 31 | 38 | 38 | 107 | 2 |
| | Q5 | 1-Jul-20 | 4 | 1 | 0 | 5 | 0 |
| | Q6 | 1-Jul-20 | 18 | 4 | 11 | 33 | 0 |
| | Q7 | 1-Jul-20 | 29 | 9 | 11 | 49 | 4 |
| | Q8 | 1-Jul-20 | 31 | 14 | 16 | 61 | 2 |
| | Q9 | 1-Jul-20 | 0 | 0 | 1 | 1 | 0 |
| | Q10 | 1-Jul-20 | 22 | 12 | 4 | 38 | 1 |
| | Q11 | 1-Jul-20 | 0 | 0 | 0 | 0 | 0 |
| | Q12 | 1-Jul-20 | 3 | 0 | 1 | 4 | 0 |
| | Q13 | 1-Jul-20 | 1 | 0 | 1 | 2 | 0 |
| | Q14 | 1-Jul-20 | 86 | 21 | 26 | 133 | 5 |
| | Ant1 | 1-Jul-20 | 14 | 1 | 5 | 20 | 3 |
| Plot 4 | Q1 | 18-Nov-20 | 41 | 26 | 15 | 82 | 2 |
| | Q2 | 18-Nov-20 | 90 | 115 | 104 | 309 | 17 |
| | Q3 | 18-Nov-20 | 15 | 14 | 7 | 36 | 2 |
| | Q4 | 18-Nov-20 | 52 | 76 | 36 | 164 | 9 |
| | Q5 | 18-Nov-20 | 397 | 208 | 246 | 851 | 13 |
| | Q6 | 18-Nov-20 | 116 | 48 | 55 | 219 | 18 |
| | Q7 | 18-Nov-20 | 74 | 170 | 116 | 360 | 8 |
| | Q8 | 18-Nov-20 | 56 | 62 | 36 | 154 | 7 |
| | Q9 | 18-Nov-20 | 108 | 235 | 112 | 455 | 6 |
| | Q10 | 18-Nov-20 | 299 | 197 | 107 | 603 | 18 |
| | Q11 | 18-Nov-20 | 106 | 186 | 67 | 359 | 19 |
| | Q12 | 18-Nov-20 | 220 | 66 | 69 | 355 | 12 |
| | Q13 | 18-Nov-20 | 147 | 151 | 94 | 392 | 7 |
| | Q14 | 18-Nov-20 | 79 | 116 | 66 | 261 | 26 |
| | Ant1 | 18-Nov-20 | 228 | 37 | 41 | 306 | 25 |