Iron Bridge

Pityrodia sp. Marble Bar Research and Conservation Plan

North Star Project

August 2020
662MIC0020-5500-PL-EN-0001

	Pityrodia sp. Marble Bar Research and Conservation Plan		662MIC0020-5500-PL-EN-0001
Revision Number	1		**18/08/2020**
Status	**IFU - ISSUED FOR USE**		
Summary of Changes	Section 2.2.2. Glacier Valley Flora and Vegetation Survey added. Updated Conservation Status of Pityrodia (Section 1.2), and deletion of Section 2.2.5 – to account for species listing as Threatened. Indicative timeline in Section 6 updated, and reference to dates in main body removed.		
Author	Todd Edwards	Signature	18/08/2020
Checked	Jared Nelson	Signature	18/08/2020
Approved	Jarrad Donald	Signature	18/08/2020
Confidentiality	**FORTESCUE STAFF & CONTRACTORS**	**Publish on Extranet**	☐ Yes ☒ No
Review Date	**N/A**		

Revision History

Author	Checker	Approver	Rev No.	Status	Issued Date
Ecoscape	**Joshua Levett**	**Ian Zlatnik**	0	**IFU**	6/06/2017

TABLE OF CONTENTS

List of Tables

List of Graphs

List of Plates

LIST OF FIGURES

1. INTRODUCTION

1.1 Project Background

In January 2015 FMG Iron Bridge (Aust) Pty Ltd received environmental approval, subject to a number of conditions, to construct and operate an open cut iron ore mine site and associated infrastructure (roads, administration buildings, accommodation camp, borefield and slurry pipeline), approximately 110 km south southeast of Port Hedland (EPA, 2014a). The project, known as the North Star Magnetite Project, also incorporates the North Star Hematite Project for which environmental approval, subject to a number of conditions, had already been granted (EPA, 2014b).

Ministerial Statement No. 993 *Statement That a Proposal May be Implemented (Pursuant to the Provisions of the Environmental Protection Act 1986): North Star Magnetite Project* (MS993) (EPA, 2014a) dated 05 January 2015, details the environmental approvals conditions including those associated with conservation significant flora and vegetation.

At the time of approval, *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4), shortened to '*Pityrodia* sp. Marble Bar' for the remainder of this document, was listed as a P1 Priority Flora species. MS993 detailed requirements for an Infrastructure Plan that demonstrated that loss of plants was avoided or minimized (Condition 6) and a regional survey plan (Condition 7). Within Condition 7 was a series of requirements if *Pityrodia* sp. Marble Bar was gazette as a Declared Rare Flora under the *Wildlife Conservation Act 1950*, detailed below:

7-8 In the event that Pityrodia sp. Marble Bar is DRF under the Wildlife Conservation Act 1950, the proponent shall within six months or as agreed in writing from the CEO:

(i) Prepare and submit a *Pityrodia* sp. Marble Bar Research and Conservation Plan to the CEO, and seek written approval from the CEO, on the advice of the Department of Parks and Wildlife, that the *Pityrodia* sp. Marble Bar Research and Conservation Plan meets the requirements of condition 7-9.

7-9 The *Pityrodia* sp. Marble Bar Research and Conservation Plan identified in condition 7-8(i) shall include details on research to be undertaken into the habitat, biology and conservation of the species;

(i) details of suitable conservation measures such as seed collection and germplasm storage, seeding or translocation trials to be undertaken to determine the likelihood of successful establishment, during mine site rehabilitation or other suitable measures, for conservation of the species;

(ii) timeframes and responsibilities for the implementation of proposed conservation measures; and

(iii) a monitoring programme and criteria for determining the efficacy of proposed conservation measures.

7-10 Prior to disturbing any individuals of *Pityrodia* sp. Marble Bar within the Mine Development Envelope the proponent shall implement the *Pityrodia* sp. Marble Bar Research and Conservation Plan required by condition 7-9.

7-11 The proponent shall submit a report to the CEO documenting the results of the *Pityrodia* sp. Marble Bar Research and Conservation Plan, identifying the findings of the research required by condition 7-9 (i), and the success of the conservation measures required by condition 7-9 (ii), within 6 months of completion of the measures set out in the approved plan.

Pityrodia sp. Marble Bar was gazetted as Threatened Flora in November 2015, enacting the requirements of Conditions 7-8 to 7-11. Fortescue have received a time extension for the development of the Conservation and Research Plan until the Project commences. Table 1 summarises the Ministerial Statement requirements.

Table 1: Conditions relating to this Plan

Condition	Requirement	In this document	Comment
7-8	In the event that *Pityrodia* sp. Marble Bar is DRF under the Wildlife Conservation Act 1950, the proponent shall within six months or as agreed in writing from the CEO: (i) Prepare and submit a *Pityrodia* sp. Marble Bar Research and Conservation Plan to the CEO, and seek written approval from the CEO, on the advice of the Department of Parks and Wildlife, that the Pityrodia sp. Marble Bar Research and Conservation Plan meets the requirements of condition 7-9.	Y	This document represents the *Pityrodia* sp. Marble Bar research and conservation plan.
7-9	The *Pityrodia* sp. Marble Bar Research and Conservation Plan identified in condition 7-8 (i) shall include details on research to be undertaken into the habitat, biology and conservation of the species		
7-9(i)	details of suitable conservation measures such as seed collection and germplasm storage, seeding or translocation trials to be undertaken to determine the likelihood of successful establishment, during mine site rehabilitation or other suitable measures, for conservation of the species	Y	Addressed in Sections 4.5 and 1.1. Sections 4.1 – 4.4 outline research required for a greater understanding of the species to ensure the success of these measures.
7-9(ii)	timeframes and responsibilities for the implementation of proposed conservation measures.	Y	Addressed in Sections 4.5 and 5.
7-9(iii)	a monitoring programme and criteria for determining the efficacy of proposed conservation measures.	Y	Requirements for a monitoring programme included in Section 4.5.

Condition	Requirement	In this document	Comment
7-10	Prior to disturbing any individuals of *Pityrodia* sp. Marble Bar within the Mine Development Envelope the proponent shall implement the *Pityrodia* sp. Marble Bar Research and Conservation Plan required by condition 7-9.	Y	Dates for implementing various components addressed in Sections 4.1 – 5.
7-11	The proponent shall submit a report to the CEO documenting the results of the *Pityrodia* sp. Marble Bar Research and Conservation Plan, identifying the findings of the research required by condition 7-9 (i), and the success of the conservation measures required by condition 7-9 (ii), within 6 months of completion of the measures set out in the approved plan.	Y	Reporting of research and findings as per triggers identified within this document.

1.2 Pityrodia sp. Marble Bar Conservation Status

During baseline surveys for the North Star Magnetite Project, *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) was listed as Priority 1 flora, but in November 2015 it was gazette as Schedule 2 - Threatened Flora (Declared Rare Flora) under the *Wildlife Conservation* (WC) Act 1950.

The WC Act has subsequently been superseded by the Biodiversity Conservation (BC) Act 2016, with *Pityrodia* sp. Marble Bar listed as Threatened (Endangered).

The species has also been listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation* (EPBC) Act 1999 since 11 May 2018.

1.3 Scope

This document represents the Research and Conservation Plan required as part of the environmental approval of the North Star Magnetite Project.

1.4 Objective

The objective of this research and conservation plan is to increase the knowledge base for *Pityrodia* sp. Marble Bar for the purpose of increasing the prospect of successful re-establishment of this species on a rehabilitated landscape, in order to maintain its current distribution and population.

2. BACKGROUND

2.1 Rationale Underpinning Research

Conservation of rare species can be divided into the following categories (based on Botanic Gardens and Parks Authority, 2008)

- *in situ* conservation i.e. conservation (preservation) of the species in the site of its original natural position;
- augmentation of existing populations including:
  - rehabilitation of disturbed areas;
  - increasing population size;
  - increasing population density.
- *translocation to create new populations in undisturbed areas;*
- *restoration on re-created surfaces (i.e. minesite terraforming and rehabilitation);*
- *ex situ conservation including:*
  - propagation of living material;
  - seed storage;
  - germplasm storage.

Where there is little background information, baseline research is required to understand the basic ecological and physiological characteristics of the subject species in order to increase the potential success of any conservation and restoration activities. Baseline research includes:

- *studying population demography and recruitment, thereby allowing prediction of future population changes;*
- *investigating habitat requirements including water relations, topological requirements and associated vegetation;*
- *investigating ecological factors that may limit species distribution, establishment and survival including soil mycorrhiza, pollination and seed predation;*
- *assessing threatening processes e.g. predation, drought and fire;*
- *investigating reproductive biology including pollination, seed set and viability, seed dispersal vegetative reproduction;*
- *seed biology including persistence;*
- *propagation methods;*

- *monitoring to investigate the effectiveness of restoration, translocation and rehabilitation efforts;*
- *comparative studies with closely related species (if such information is available).*

2.2 Literature Review

2.2.1 Taxonomy

Pityrodia sp. Marble Bar has not been formally taxonomically described and published with a binomial scientific name. It is currently known by its phrase name of *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4).

Pityrodia sp. Marble Bar was first collected by Greg Woodman and David Coultas in August 2010 from Unallocated Crown Land near the Strelley and Wallareenya Station boundaries, east of the Strelley River, approximately 155 km west of Marble Bar and 105 km south southeast of Port Hedland (Western Australian Herbarium, 2016).

Pityrodia sp. Marble Bar has been informally described (below) in the *Rare and Priority Plants of the Pilbara* mobile app edition (Rio Tinto & DPAW, 2015).

Description

Erect woody *shrubs* 0.6-1.5 m high. Stems and branches densely clothed with creamish-white branched hairs that often become white to pale yellow or pale orange upwards. *Leaves* petiolate; lamina ovate or oblong-ovate with rounded or obtuse apices, more or less oblique and cordate or rounded at the base, 3-6 cm long, 2.0-3.8 cm broad, flat, crenulate, rugose above, the reticulate nerves inconspicuous on the under surface, densely greenish-grey tomentose; petiole thick, tomentose, adaxially grooved, (0.5-) 1-2 cm long. *Inflorescences* cymose in the upper axils; cymes arranged into more or less lax leafy panicles, densely woolly-tomentose, rarely exceeding the leaves; primary peduncles (5-) 14-30 mm long. *Flowers* pedicellate, 3-7 or more in a cyme; pedicel woolly tomentose, 3-6 mm long, pinkish to pale lilac in colour; bracts sessile, linear-lanceolate, woolly-tomentose on abaxial surface, glandular and hairy on adaxial surface, flat, entire, 2-4 mm long, 0.5-1 mm broad; bracteoles sessile, resemble bracts, 1-3 mm long, 0.5 mm broad. *Calyx* persistent, divided almost to the base into 5 lobes, 7-8 mm long, woolly-tomentose outside, glabrous but sparsely glandular inside; lobes linear, 1-nerved, 4-6 mm long, 0.5-1 mm broad; tube shallow, 0.5-1 mm long. *Corolla* pink with purple streaks in the throat, 15-18 mm long, sparsely glandular and tomentose outside, glabrous inside except a dense hairy ring above the ovary, and sparse villous hairs extending to the large anterior lobe of the lower lip; anterior lobe broadly elliptic or almost orbicular in outline, entire, 3-6 mm long, 4-6 mm broad; lateral lobes broadly ovate, 1-2.5 mm long, 2-3 mm broad; upper lobes oblong-ovate, 2-3 mm long, 2-3 mm broad at the base; tube abruptly dilated within the calyx, about as long as the calyx, 9-11 mm long, 6-7 mm broad at the top end. *Stamens* slightly exserted; filaments glabrous, filiform, the lower pair 5-7 mm long, the upper pair 4-5 mm long; anthers

more or less orbicular in outline, 1.7-2 mm long, 1-2 mm broad, lobes oblong, appendaged at the lower ends of both the cells. *Ovary* globose, densely tomentose, seated on a thick glabrous disk, ± 1 mm in diameter; style slightly exserted, glabrous with a few hairs towards the base, filiform, 6-11 mm long, shortly 2-lobed at the apex; ovules attached near the top with short funicles. Fruit ovoid-globose, tomentose with branched hairs; seeds not seen.

Ecology

Grows along rocky slopes associated with various geology, often near cliffs. Plants flower and fruit from May to September.

Distribution

Endemic to the Pilbara region, restricted to rocky slopes near Marble Bar.

Additional Notes

Pityrodia sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) is most closely related to *Pityrodia obliqua*. It differs from this species in having leaves with a higher density of hairs particularly on the undersurface of leaves where the tertiary venation is inconspicuous (tertiary venation conspicuous in *P. obliqua*), longer calyx lobes (7-8 mm compared to 5-6 mm in *P. obliqua*), longer corolla (15-18 mm long compared to 12-15 mm in *P. obliqua*) and longer anthers 1.7-2.0 mm long compared to 1-1.3 mm long in *P. obliqua*).

2.2.2 Previous Surveys

The reports summarised below have identified *Pityrodia* sp. Marble Bar as occurring within their study areas, or relate to surveys where the species was considered to have potential to occur. A brief summary of relevant information within the reports is included below.

Atlas Iron

Supplementary Botanical Surveys, Rare Flora Searches, Assessment of Vegetation Condition and Identification of Groundwater Dependent Ecosystems for the Sulphur Springs Project (Trudgen, 2007); although this report was not sighted during a literature review, it is referenced in the *Abydos Stage 2* report below (Woodman Environmental Consulting, 2013). It appears that a species of *Pityrodia* (potentially known as *Pityrodia* Mt Panorama at the time, now *Pityrodia* sp. Marble Bar) had been recorded during the field surveys associated with this project. It is therefore most likely to be the first publication recording the existence of this species.

Abydos Direct Shipping Ore Project Flora Assessment, Floristic Community Type Mapping and Impact Assessment (Woodman Environmental Consulting, 2009); This report was not sighted during a literature review however it is referenced in the *Mount Dove* report below (Woodman Environmental Consulting 2011) It appears that the species then known as

Pityrodia sp. Nov (since renamed as *Pityrodia* sp. Marble Bar) had been recorded during the surveys associated with the Abydos project.

Mount Dove Direct Shipping Ore Project Flora and Vegetation Studies (Woodman Environmental Consulting, 2011); this report of a Level 2 flora and vegetation survey of Atlas Iron's Mount Dove tenement, located approximately 68 km south of Port Hedland on Indee Station, identified a new (currently unknown to science) species of *Pityrodia* previously known as *Pityrodia* sp. Nov and recently known by the phrase name *Pityrodia* sp. Marble Bar as part of the desktop assessment, noting that it had been recently listed as Priority 1 and had been recorded at Abydos. However it was not recorded from the Mt Dove Project area.

Abydos Direct Shipping Ore Project Stage 2 Flora and Vegetation Impact Assessment (Woodman Environmental Consulting, 2013); this report details the flora and vegetation survey for the Abydos DSO expansion and an additional targeted searches for *Pityrodia* sp. Marble Bar that was conducted with the aims of documenting the species distribution within the disturbance envelope and identifying an extended range and population of the species. The survey identified 1 280 individual plants over 16 populations from this and all previously known surveys (Trudgen, 2007; Woodman Environmental Consulting, 2012, both reports not sighted), of which 143 were within the Stage 2 area. It was considered possible that *Pityrodia* sp. Marble Bar may be susceptible to issues associated with dust deposition due to its hairy leaves and altered hydrology resulting from the project development. Ecological and physiological observations included in this report were:

- *Pityrodia* sp. Marble Bar usually occurred as isolated clumps of individual on very steep, rocky conglomerate and granite slopes, which were almost always south facing
- most populations consisted of less than 100 plants although there were some populations of over 200 individuals
- the 2013 survey area had largely been recently burnt (within the last six months) in a high intensity fire, and individual *Pityrodia* sp. Marble Bar plants were observed to have resprouted rapidly from a woody rootstock and seedlings were also observed at a number of locations adjacent to resprouting individuals.

FMG Iron Bridge

Canning Basin Borefield and Pipeline Single Phase Flora and Vegetation Assessment (660NS-0000-AS-EN-0001) (Ecologia Environment, 2012a); *Pityrodia* sp. Marble Bar was identified by the desktop assessment as unlikely to occur within the study area. None were recorded, indicating that the predictions of suitable habitat were accurate.

North Star Access Corridor Flora, Vegetation, Vertebrate Fauna and Fauna Habitat Assessment (NS-AS-EN-0003) (Ecologia Environment, 2012b); *Pityrodia* sp. Marble Bar was identified by the desktop assessment as unlikely to occur within the study area. None were recorded, indicating that the predictions of suitable habitat were accurate. .

North Star Flora and Vegetation Assessment (Ecologia Environment, 2012c); this survey identified 541 plants from 14 loci (representing 14 populations separated by more than 500 m) within the North Star mine site study area. Ecologia Environment considers that *Pityrodia* sp. Panorama (reported in Mattiske 2007 and URS 2007; neither report sighted) is likely to be the same species, although no specimens from the Mattiske survey have been submitted to the WA Herbarium. *Pityrodia* sp. Panorama was reported as occurring approximately 10 km east of the North Star study area and consisted of more than 257 plants. *Pityrodia* sp. Marble Bar was reported as occurring on steep sandstone hills. *Pityrodia* sp. Marble Bar was most frequently associated with vegetation type **AaTw^4** and to a lesser extent **SpTl**, **Tl** and **GwTe**, described below: (Mattiske, 2007 and URS, 2007)

AaTw^4: *Triodia* hummock grassland, described as *Acacia acradenia* and *Acacia inaequilatera* sparse mid shrubland over *Triodia wiseana* and *Triodia lanigera* hummock grassland

SpTl: *Triodia* open hummock grassland, described as *Solanum phlomoides* isolated low shrubs, over *Triodia lanigera* open hummock grassland

Tl: *Triodia* hummock grassland, described as *Triodia lanigera* open hummock grassland

GwTe: *Triodia* hummock grassland, described as *Grevillea wickhamii* sparse mid shrubland over *Triodia epactia* or *Triodia schinzii* open hummock grassland.

Correlating recent *Pityrodia* sp. Marble Bar survey results with the various vegetation types mapped by Ecologia Environment (2012c) *Pityrodia* sp. Marble Bar is known to occur in the following vegetation types (in order of highest number of plants recorded):

AtEm: *Acacia tumida*, *Acacia orthocarpa* and *Grevillea wickhamii* open shrubland over *Eriachne mucronata* isolated tussock grasses; associated *Triodia* spp. are *T. pungens*, *T. schinzii* and *T. wiseana* on rocky hills and plains

AaTw^4: *Acacia acradenia* and *Acacia inaequilatera* sparse mid shrubland over *Triodia wiseana* and *Triodia lanigera* hummock grassland on rocky hills and plains

GwTe: *Grevillea wickhamii* sparse mid shrubland over *Triodia epactia* or *Triodia schinzii* open hummock grassland associated with drainage lines

Tl: *Triodia lanigera* open hummock grassland on rocky outcrops

At: *Acacia tumida*, *Grevillea wickhamii* and *Indigofera monophylla* shrubland (associated *Triodia* spp. are *T. longiceps* and *T. pungens*) on shrubby drainage-lines

AiTb: *Acacia inaequilatera*, *Acacia acradenia* and *Grevillea wickhamii* sparse shrubland, over *Triodia basedowii* and *Triodia wiseana* hummock grassland on sandy and gravelly plains

SpTl: *Solanum phlomoides* isolated low shrubs over *Triodia lanigera* open hummock grassland on granite sandy plains and outcrops

Tp: *Triodia pungens* open hummock grassland on granite sandy plains and outcrops

AaTw^3: *Acacia acradenia*, *Acacia tumida* and *Grevillea wickhamii* open shrubland over *Triodia wiseana* hummock grassland on rocky hills and plains

AoTw: *Acacia orthocarpa* open tall shrubland over *Triodia wiseana* open hummock grassland on rocky hills and plains

Tw1: *Triodia wiseana* and *Triodia schinzii* hummock grassland on rocky hills and plains

AsTl: *Acacia stellaticeps* sparse low shrubland over *Triodia longiceps* hummock grassland on sandy and gravelly plains.

Pityrodia sp. Marble Bar Targeted Flora Survey (Ecologia Environment, 2012d); this survey recorded 654 additional *Pityrodia* sp. Marble Bar and confirmed the identification of *Pityrodia* sp. Panorama (and therefore the earlier records) as the same species. As a result, it was reported that 1 521 *Pityrodia* sp. Marble Bar plants were known at the time, with the total known population occupying an approximate 20 km north-south and 30 km east-west area. The species habitat was recorded as occurring within the Capricorn land system, most frequently on steep, rocky areas with a south or east aspect.

Associated vegetation, as indicated on the included Threatened and Priority Flora Report Forms:

- *Senna artemisioides low open shrubland over Triodia sp. hummock grassland*
- *Scattered Cymbopogon sp. over Triodia hummock grassland*
- *Triodia sp. hummock grassland; open Triodia sp. hummock grassland*
- *Corymbia open woodland over Acacia tumida over Triodia hummock woodland*
- *Corchorus sp. and Senna artemisioides over Triodia hummock grassland*
- *Acacia tumida shrubland over Triodia hummock grassland*
- *Senna glutinosa and Senna artemisioides low open shrubland over Triodia sp. hummock grassland.*

North Star Slurry and Infrastructure Corridors Conservation Significant Flora and Vegetation Assessment (Ecologia Environment, 2015a); this report detailed a conservation significant flora and vegetation assessment of the Slurry and Infrastructure Corridors associated with the North Star Project. No *Pityrodia* sp. Marble Bar had previously been recorded in these areas; none were recorded during this survey although an opportunistic observation of 12 plants were recorded 2 km north of the infrastructure area.

Re: Pityrodia sp. Marble Bar Revised Species Distribution Model (letter; NS-PL-EN-0006) (Ecologia Environment, 2015b); this letter details methods and results of a revised species

distribution model run using MaxEnt. The aim of reducing the search area to minimise field effort was not met as the modelling did not provide additional refinement.

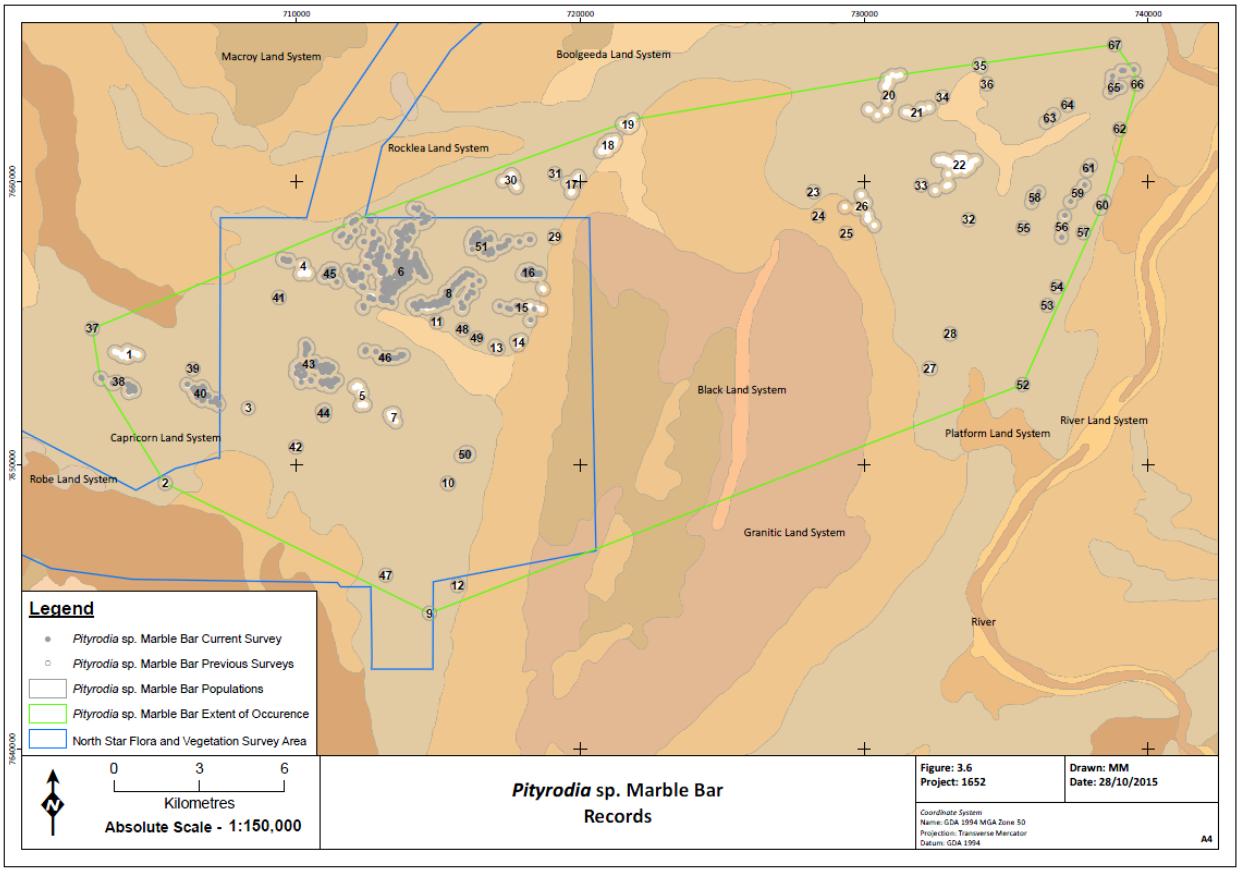
FMG Iron Bridge North Star Stage 2 Pityrodia sp. Marble Bar Regional Survey 2015 (Ecologia Environment, 2016); this report details the findings of a regional survey for *Pityrodia* sp. Marble Bar that covered areas that had previously been identified as potential habitat targets using species distribution modelling. The survey resulted in an additional 7 473 individual plants being recorded, including juveniles and seedlings, bringing the total known population to 9 848. The total number of populations, defined as groups of plants separated by >500 m from the nearest neighbour, has been assessed as 67. The known extent of this species was increased to 422.4 km^2, with almost all occurring on the Capricorn land system (six records were recorded from the Rocklea land system). There were no new records of this species from the further distance target survey areas north of Nullagine, north and northwest of Marble Bar, or south or southeast of the known occurrence. Field observations included:

- the recording of two colour forms (a new green, rather than grey form, having yellow rather than white hairs on the stems and leaves, pink rather than white hairs on the sepals and a possibly more open habit; the green form being far less common and recorded from only one population
- plants resprout following fire and flower and fruit within one year of being burnt
- juveniles and seedlings were only recorded in recently burnt areas, some of which had flowered within one year of germination
- two insect pollinators were observed; a Jewel Beetle was most frequently observed however feral Honey Bees were also noted.

The distribution and extent of *Pityrodia* sp. Marble Bar is indicated on Figure 1 (Figure 3.6 from Ecologia Environment, 2016), and includes records from the Atlas Abydos DSO surveys (Woodman Environmental Consulting, 2013) as well as every known population recorded by Ecologia Environment.

Glacier Valley Extension Flora and Vegetation Survey, North Star Project (Ecoscape 2018); this survey located one additional *Pityrodia* sp. Marble Bar plant within 200 m of the single plant associated with Population 12. Six new populations (designated Populations 69 to 74) were recorded from the survey area, totalling 259 plants, plus two additional populations recorded outside of the survey area (designated Populations 75 and 76) totalling seven plants. The total number of new plants recorded from this survey was 267, increasing the total number of known *Pityrodia* sp. Marble Bar plants to 10,115.

Figure 1: *Pityrodia* sp. Marble Bar Records (from Ecologia Environment, 2016)



2.2.3 Management Plans: Atlas Iron Abydos DSO Project

Significant Species Management Plan Abydos DSO Project (Coffey Environments, 2014); this Plan confirms that *Pityrodia* sp. Marble Bar, then listed as Priority 1, was recorded from within the Abydos DSO project area and outside, including the Gorge range near Sulphur Springs. The Plan records the required management measures as recording all locations of individual plants and that clearing should be avoided as far as reasonably practicable and kept to the minimum necessary for the safe construction and operation of the project. Monitoring and reporting are listed as requirements of the native vegetation clearing permit. Floristic community types listed as habitat for *Pityrodia* sp. Marble Bar are:

- FCT 1: Low isolated trees of Corymbia hamersleyana over tall sparse shrubland of mixed species including Acacia species and Grevillea wickhamii subsp. hispidula over low sparse shrubland of mixed species including Corchorus laniflorus and Bonamia rosea over low grassland dominated by Triodia epactia and/or Chrysopogon fallax on red-brown sandy and clay loams on floodplains and in broad drainage lines
- FCT 2a Tall open shrubland of mixed species dominated by Grevillea wickhamii subsp. hispidula, Acacia tumida var. pilbarensis and A. orthocarpa over low sparse shrubland of mixed species including Dampiera candicans, Goodenia stobbsiana and Corchorus

laniflorus over low hummock grassland dominated by Triodia species on red-brown silty loams over ironstone or sandstone on hill crests and slopes

- FCT 4: Low isolated trees of Corymbia hamersleyana or Eucalyptus leucophloia subsp. leucophloia over tall sparse shrubland of mixed species including Acacia species and Grevillea wickhamii subsp. hispidula over low sparse shrubland of mixed species including Acacia species and Dampiera candicans over low hummock grassland of mixed Triodia species on brown sandy and clay loams over ironstone, calcrete or sandstone on hill crests and slopes, and occasionally on undulating plains and low rises.

2.2.4 Vouchered Specimens

As of August 2016, ten specimens of *Pityrodia* sp. Marble Bar have been vouchered at the Western Australian Herbarium (Western Australian Herbarium, 2016). Excluding location information, the collecting information associated with these specimens is included in Table 2 below.

Table 2: Pityrodia sp. Marble Bar voucher specimen information

Collector/Collection No.	Date	Site Description	Frequency
Coultas, D.; Jones, T. Coll No: DCTJ - 04	31 May 2013	Granite or conglomerate cliff/slope. Slope: very steep. Skeletal red clay loam.	10 plants
Coultas, D.; Jones, T. Coll No: DCTJ - 02	29 May 2013	Granite or conglomerate steep slope. Skeletal red clay loam.	11 plants
Coultas, D.; Jones, T. Coll No: DCTJ - 01	29 May 2013	Granite or conglomerate steep slope. Skeletal red clay loam.	11 plants
Woodman, G.; Coultas, D. Coll No: GWDC-Opp1	22 September 2011	Mid slope of very steep ironstone hill slope. Red brown sandy loam.	-
Macdonald, M.J. Coll No: MJM - 1321 - 06	4 July 2011	-	13 plants
Macdonald, M.J. Coll No: MJM - 1321 - 07	4 July 2011	-	19 plants
Woodman, G.; Coultas, D. Coll No: GWDC Opp 4	30 August 2010	Midslope of very steep ironstone hillslope, base of small cliff, SW facing. Skeletal red-brown sandy loam over massive ironstone. Vegetation: With *Triodia* spp.	Approx. 50 plants
Woodman, G.; Coultas, D. Coll No: GWDC Opp 3	30 August 2010	Base of very steep sandstone hillslope, S-facing, within gorge. Skeletal brown sandy loam over massive sandstone. Vegetation: Tall shrubland of *Terminalia canescens* and *Acacia tumida* var. *pilbarensis* over hummock grassland of *Triodia longiceps*, with *Eriachne mucronata*, *Sarcostemma viminale* subsp. *australe*.	Approx. 27 plants
Coultas, D. Coll No: DCCV Opp14	28 May 2010	S side of small gully. Steep. Skeletal clay loam over sandstone/conglomerate.	6 plants
Coultas, D. Coll No: DCCV Opp03	26 May 2010	Sandstone or conglomerate slope. Very steep. Skeletal red clay loam.	11 plants

2.2.5 Ecoscape Observations August 2016

Ecoscape visited the North Star site in August 2016 and made the following observations:

- the habitat of conglomerated rock and steep slopes were confirmed; examples shown in Plate 1 and Plate 2. Plants were also observed in minor depressions and minor creeklines high in the landscape, all on very rocky terrain;
- it was confirmed that mature plants resprout following fire (Plate 2 - Plate 4);
- it was confirmed that the seeds germinate following fire. Seedlings were observed close to mature plants, generally within 1-2 m although some were observed up to 5 m away, downslope; examples shown in Plate 3 and Plate 4;
- with respect to the colour variation reported by Ecologia Environment (2016) in population 50: whilst there was colour variation, the colour variation within vegetative parts (leaves and stems) appeared to be related to new growth, which was more green with yellow hairs rather than grey with white hairs on mature parts (Plate 5). There were no whole plants observed that displayed the colour variation suggested by Ecologia Environment. There was, however, gradation in the colour of the calyx hairs and overall impression of colour of flowering parts, ranging from the more usual white hairs giving the impression of grey colouring (Plate 6) to pink hairs, giving a pink blush or, where more strongly coloured, an overall pink appearance (Plate 7-Plate 8). The stronger pink colour was only observed in population 50 however only few populations were visited so it cannot be conclusively stated that population 50 is significantly different to others.
- jewel beetles were observed pollinating the flowers (Plate 9); they appear to be the same species as previously reported
- ants were also observed in the flowers, and probably also contributed to pollination (Plate 10, although no ants were photographed actually in flowers)
- no leaves or plants were observed to have been grazed or browsed indicating a lack of invertebrate and vertebrate (including feral livestock and native herbivores like kangaroos) interest in the plant foliage
- insect borer holes were observed in old wood of the plants (Plate 11 and Plate 12).

Plate 1: *Pityrodia* sp. Marble Bar Habitat

Plate 2: *Pityrodia* sp. Marble Bar Habitat

Plate 3: Burnt *Pityrodia* sp. Marble Bar with seedlings to the right of plant on right side

Plate 4: Burnt *Pityrodia* sp. Marble Bar with seedlings

Plate 5: *Pityrodia* sp. Marble Bar displaying different colour on new growth

Plate 6: *Pityrodia* sp. Marble Bar showing normal grey appearance of calyx

Plate 7: *Pityrodia* sp. Marble Bar showing pinkish appearance of calyx

Plate 8: *Pityrodia* sp. Marble Bar showing strong pink colouration of calyx (population 50).

Plate 9: Jewel Beetle pollinating *Pityrodia* sp. Marble Bar

Plate 10: Ant on *Pityrodia* sp. Marble Bar

Plate 11: Insect emergence holes in old wood

Plate 12: Insect emergency holes in old wood

2.3 Updated MaxEnt Modelling

There have been a number of targeted surveys for *Pityrodia* sp. Marble Bar prior to developing this research and conservation plan, including areas proposed for clearing for mine and infrastructure as well as a regional survey to identify additional populations of the species. The target areas outside of the development envelopes (i.e. regional survey area) had been identified by MaxEnt ('maximum entropy', Phillips et al, 2006) modelling (Ecologia Environment, 2015b; 2016) that identified areas having potential habitat. The recent regional survey (Ecologia Environment, 2016) identified a minor range extension of *Pityrodia* sp. Marble Bar but failed to detect any new populations in the more widespread areas identified as being potential habitat by the MaxEnt modelling.

In order to measure the effectiveness of the current state of knowledge on the definition of *Pityrodia* sp. Marble Bar's regional distribution, a secondary MaxEnt model was run with additional locational information which was unavailable at the time the previous model was created (i.e. new population records and pseudo-absence locations based on a sampling bias created from areas which were searched during the regional survey but did not record *Pityrodia* sp. Marble Bar). The aim of the secondary model was to prove that, with the additional information, there are no new areas identified where *Pityrodia* sp. Marble Bar may occur, but have not yet been searched.

2.3.1 MaxEnt Methods

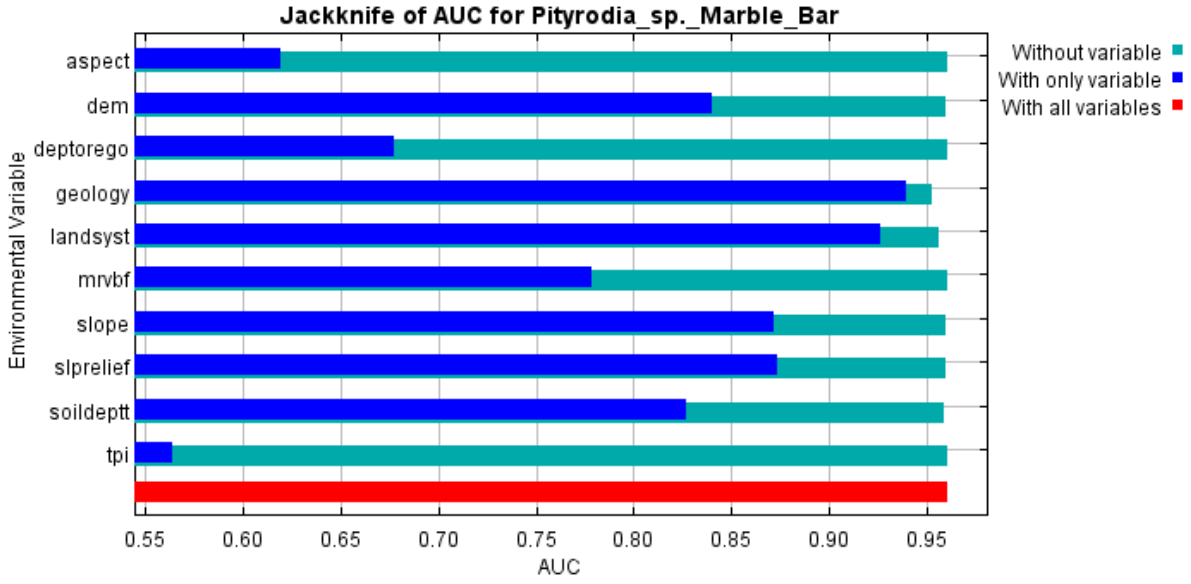
The methodology for the current model was aligned with that used within the *Pityrodia* sp. Marble Bar regional survey plan (Ecologia Environment, 2015b). The environmental variables

used and the internal settings of the model were consistent between models, with the largest source of vitiation coming from the new *Pityrodia* sp. Marble Bar locational records (4,983 records) and the absence locations in the form of a sampling bias.

2.3.2 MaxEnt Results

Evaluation of the performance of the model revealed an Area Under the Curve (AUC) value of 0.960; averaged across all model replicates. An AUC value close to 1.0 indicates that the performance of the predictive power of model is high. An AUC of 0.5 would indicate that the model is operating at no better than random chance (Young et al, 2011). Graph 1 shows the predictive value of each environmental variable, and indicates that land systems and geology are the best performers in terms of predicting the location of *Pityrodia* sp. Marble Bar, which is consistent with the model results from the regional survey plan. Good predictive performance of the model and results consistent with previous observations indicate that the current model is of high accuracy and quality.

Graph 1: Predictive value of MaxEnt Modelling

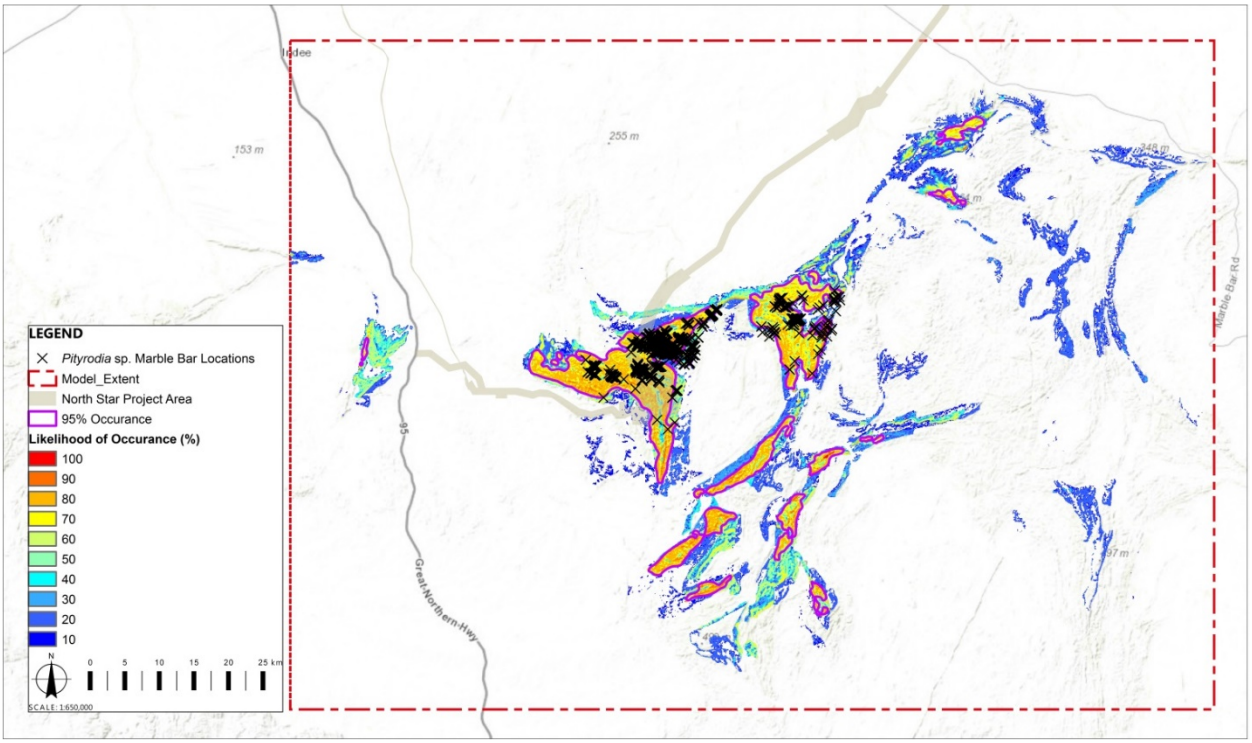


Explanation of Figure 2 variables:

- aspect – the compass direction a slope is facing
- DEM – Digital Elevation Model, representing terrain relief
- deptoreg – depth to regolith
- geology – rocks and soils
- landsys – land systems (Van Vreeswyk et al. 2004)
- mrvbf – Multi-Resolution Valley Bottom Flatness; an index distinguishing valley bottoms from hillslopes and identifies areas of erosion and deposition (Gallant & Dowling, 2003)
- slope – changes in land relief (%)
- slprelief – an index that compares slope and relief over a 300 m radius
- soildepth – soil depth
- tpi – Topographic Position Index, where landscapes are defined in three classes (hilltops, slopes or low areas).

The model output is depicted in Figure 3. Due to the addition of new *Pityrodia* sp. Marble Bar locational records and absence areas, the current iteration of the model shows a more constrained and realistic distribution of *Pityrodia* sp. Marble Bar compared to the model results in the survey plan. Ninety five percent of known *Pityrodia* sp. Marble Bar locations (indicated by 'X') can be found within the 60% or above likelihood category of predicted occurrence; displayed in purple in Figure 3. Excess areas of *Pityrodia* sp. Marble Bar occurrence identified by the model have been visited in previous targeted surveys, and absence confirmed. This indicated that no new areas have been identified by the inclusion of new information into the model and that the current extent of *Pityrodia* sp. Marble Bar is accurate.

Figure 2: MaxEnt model output



2.3.3 MaxEnt Conclusion

The resultant output did not identify new locations where a high likelihood of *Pityrodia* sp. Marble Bar occurring existed that had not already been searched during the North Star Baseline or subsequent *Pityrodia* sp. Marble Bar target surveys. This indicates that the extent of the known distribution of *Pityrodia* sp. Marble Bar has likely been defined by the current survey effort.

2.4 Knowledge Gaps

2.4.1 Population Dynamics

Field observations indicate that the plants are long-lived and resprout following fire. Seedlings have been observed to have germinated following fire, including intense, hot burns.

However, there is no empirical data on growth rates or plant age. There is also no information recorded detailing seedling survival following germination, nor if there are additional triggers for germination including rainfall timing or amount following burning.

2.4.2 Breeding/Recruitment Biology

Pityrodia sp. Marble Bar plants have been observed to flower within one year of being burnt and within one year of germinating, however there is no knowledge if seed is set in these circumstances, nor correlation between plant (or stem) age and seed set.

There is no knowledge relating to seed production and storage, including if the seed is stored on the plant or shed, seed viability, seed dispersal, seed dormancy or germination triggers (other than, broadly, fire). If the seeds are shed and form part of the soil seed bank, seed persistence, dispersal and predation characteristics are unknown.

Jewel beetles and European Honey Bees (and potentially ants) have been observed pollinating the plants, however there is no knowledge in relation to the species' breeding system (e.g. cross- or self-pollination, effectiveness of each, pollen dispersal distance).

2.4.3 Response to Disturbance

There is ample evidence that *Pityrodia* sp. Marble Bar resprouts and seedlings germinate following fire, although there is no specific information regarding timing of fires, fire intervals, fire intensity (although it is understood that plants survive and seedlings germinate following apparent hot burns) or the timing or amount of rainfall required following burning.

There is no knowledge relating to seedling recruitment following disturbances other than fire (e.g. road grading and other soil disturbance), however no recruitment has been observed in these situations.

There have been no reported observations of mature plants dying following drought, however there has been no specific research relating to this aspect, for either mature or juvenile plants.

2.4.4 Habitat Requirements

Broad habitat correlations are well described, including broad soil types, land systems and structure, aspect and topography.

Review of the vegetation associated with *Pityrodia* sp. Marble Bar, as detailed above, indicates that there is no specific correlation with any particular vegetation type or species. Overall, the associated vegetation is generally shrubland dominated by various species (sometimes with a sparse tree overstorey), or grassland, most commonly dominated by either undefined *Triodia* species or one or more of several common *Triodia* species.

However, there is no known information in relation to specific hydrology within the plant root zone, nor if there are any aspect of soil chemistry that is correlated with the species' distribution, nor relating to detailed soil physical attributes like rock size.

2.4.5 DNA Investigations

There have been no DNA investigations including potential variation and gene flow between the disjunct eastern and western populations.

2.4.6 Rehabilitation Trials

There have been no rehabilitation trials conducted.

2.4.7 Ex Situ Conservation

There has been no ex situ conservation of this species.

3. RESEARCH AND CONSERVATION PLANNING

3.1 Areas of Research

In order to address the knowledge gaps identified in Section 2.4, this Plan will target the following areas of research:

1. *in situ* baseline research:
    (a) population dynamics (including plant death/longevity, growth rates to determine age ranges) and recruitment (including when seedlings germinate following fire; following rain, seedling survivorship)
    (b) breeding/recruitment biology including seed production and storage (including if the seed is held on the plant or released at maturity), seed viability, seed dispersal, seed dormancy and germination trigger, soil seed bank including persistence, phenology including age to first flowering and seed set, breeding systems (including pollinators), seed dispersal and predation
    (c) response to disturbance including fire (including timing, fire intervals and intensity), grazing, soil disturbance, drought, timing of rainfall after fire
    (d) detailed habitat requirements including hydrology, topography including slope, soil structure and chemistry and associated vegetation
    (e) DNA investigations including potential variation and gene flow between the disjunct eastern and western population
2. Rehabilitation trials including:
    (a) translocation i.e. potential for salvage
    (b) plant debris mulching, plant seed storage
    (c) seeding, cuttings
3. *ex situ* conservation:
    (a) seed collection storage
    (b) cryogenic germplasm storage
    (c) propagation methods including in vitro culture, cuttings and seed germination.

3.2 Research Limitations

Observations of Pityrodia sp. Marble Bar in its natural habitat indicate that the prospect of salvaging mature plants from areas to be cleared and translocating them to new areas is highly unlikely to be successful due to the nature of the substrate, which is conglomerated rock. This would lead to extensive root damage to mature plants during the removal process. However,

salvage trials using seedlings within the clearing zone are proposed, as it is anticipated that their lesser root development may increase the prospects of success.

For the same reason, there is no consideration given to using tubestock to supplement populations in undisturbed environments due to the likely extremely low survivorship as a result of the species' niche environment of small cracks and soil pockets in conglomerated rock and other extremely rocky substrate. In addition, due to the remote locations (i.e. distance from tracks) and steep terrain, there is no prospect of summer watering that would increase potential seedling survival.

Consequently, this research and conservation plan concentrates on understanding the biology of the species, *ex situ* conservation and rehabilitation trials on created habitat.

4. DETAILED RESEARCH AND CONSERVATION PLAN

The research and conservation plan addresses the following broad areas of research:

1. Population Demographics and Dynamics.
2. Reproductive Biology.
3. Environmental Associations/Habitat.
4. Conservation Genetics.
5. Restoration.
6. ex situ Conservation (see Section 5).

All works requiring the taking of plants or parts of plants will be conducted in accordance with relevant DPaW permits.

Prior to the first field work monitoring protocols will be developed to ensure all personnel undertaking the monitoring are aware of the protocols and procedures to ensure consistency and to reduce any potential for errors. Population Demographics and Dynamics.

The extent of studies will focus on accessible *Pityrodia sp* Marble Bar individuals within the North Star Ministerial Statement 993 development envelopes.

For the purposes of this research plan the following definitions will be used when describing individual plant specimens.

Table 3: Definitions of the descriptions of *Pityrodia sp.* Marble Bar.

Specimen Description	Definition
Seedling	A specimen grown from seed and never having resprouted following fire or other disturbance.
Juvenile	A specimen that has not yet flowered.
Juvenile of sufficient size	A specimen which is large and robust enough to not be detrimentally affected by the tagging process.
Mature Plant	A plant that has flowered or has woody stems

4.1 Population Demographics and Dynamics

Objective

To develop a greater understanding of the population demographics and dynamics of *in situ Pityrodia* sp. Marble Bar plants to identify significant features that will assist the overall objective of re-establishing the species on a rehabilitated landscape. The aspects of population demographics and dynamics relevant to this objective relate to seedling germination, growth and survival.

Actions

1. Population demographics and dynamics will be investigated using a number of marked plants within a monitoring plots;
2. Seedling recruitment within the monitoring plots following fire (and other disturbances, if noted), growth and survival of seedlings will be documented in detail;
3. The fire history within the vicinity of the monitoring plots will, where possible, be mapped annually; and
4. Rainfall will be documented.

Timing

Refer to Section 6.

Responsibility

IB Operations Site Environment

Criteria for Success

As a result of the proposed research, FMG Iron Bridge will have:

- documented seedling recruitment within marked plots, including distance, direction and slope from the parent plant;
- quantified seedling survival and growth, including identifying key stress periods during the year;
- described in detail any new plants or populations reported as a result of targeted searches (or as otherwise noted);
- charted fire history; and
- documented rainfall.

Methods

1. Monitoring plots will be established in accessible locations within the North Star Ministerial Statement 993 development envelopes to research seedling recruitment, growth and survival. The number of plots will be determined following statistical analysis to verify the minimum number of samples required to provide sufficient confidence. Seedlings are not required within all monitoring plots as this would limit the data collection to restricted areas, and a geographic range would provide more robust data and decrease the risk of catastrophic outcomes e.g. all plants die within the plot or the plot is burnt, and provide opportunities for additional data following new fires. However, in order to order to ensure sufficient data, at least 10 of the monitoring plots should have seedlings at the commencement of the monitoring period.

2. At least five mature plants will be located within each plot that will be 50 m x 50 m (or equivalent area where taking into account habitat), in order to cover at least 1% of the known population. The mature plants will be tagged and their physical attributes recorded at establishment only to provide basic demographic information.
3. All mature plants and juveniles of sufficient size will be marked, and seedlings mapped within the monitoring plots.
4. The monitoring plots will be established over a number of populations, and encompass a variety of topographic positions, fire histories and distance from planned disturbance. If possible, some populations should be within the eastern population.
5. The following will be recorded from each monitoring plot:
    - GPS location of monitoring plot corners
    - physical habitat (slope, aspect, topographic position, bare ground extent, rock cover including loose rock or conglomerate proportions, litter cover, time since fire). Time since fire or other disturbance will be measured in six monthly intervals using regular high resolution aerial imagery to determine time and extent of disturbance.
    - biological habitat (vegetation type description; NVIS Level V, recorded at an appropriate time when all characteristic species are identifiable, vegetation condition)
    - GPS location of all mature *Pityrodia* sp. Marble Bar plants using a GPS, marking all plants of sufficient size with a metal tag attached to the base of the plant
    - the location of seedlings, noting the distance and direction from the parent plant will be recorded where seedlings are observed. Representative photographs will also be taken to assist with re-locating plants for future monitoring.
    - record plant height, number of stems (live and dead) arising from the base and canopy cover (widest measure and perpendicular measure) and plant health (scale to be determined but likely to be similar to that used for riparian and Mulga monitoring) and include observations of grazing and browsing (once only recording), for both mature plants and seedlings
    - photographs of all monitoring plots from northwest and southeast corners, facing diagonally across the plot.
    - photograph of all mature plants with scale pole, taken from the northwest and southeast to enable identification of seedlings and their location in relation to the parent plant.
6. Study plots have been established and monitored twice yearly during 2017 and 2019 (Astron 2017, Ecoscape 2020). . Initial twice, yearly monitoring has determined that the most appropriate timing to record seedling mortality is in July-Sept (Ecoscape 2020). These plots will continue to be monitored annually throughout the project.
7. Analysis will include correlations between physical environment factors (fire, rainfall including quantity and timing) and seedling germination, survival and growth.

8. The fire history of the monitoring plots, as much as possible, will be mapped annually, and the fire history over time included in the report. The time (date) of the fire is to be included and, if known, descriptions of intensity and completeness of burn. Where available, rainfall data should also be included.

4.2 Reproductive Biology

Objective

To understand the reproductive characteristics of *Pityrodia* sp. Marble Bar that will assist with maximising the chances of successful re-establishment of the species on a rehabilitated landscape and, if necessary, for ex situ conservation efforts.

Actions

1. Record the phenology of *Pityrodia* sp. Marble Bar within the monitoring plots (i.e. when the plant is in bud, flowering and fruiting).
2. Record the reproductive status of individual plants in monitoring plots.
3. Collect reproductive material to determine seed production and maturation, and determine if seed in stored on the plant or released. Investigate seed survival rates in situ.
4. Identify if there are additional pollinators to the recorded honey bees, jewel beetle and ants.

Timing

Refer to Section 6.

Responsibility

IB Operations Site Environment

Criteria for Success

At the end of three years of investigation, there should be a thorough understanding of the reproductive biology of *Pityrodia sp.* Marble Bar including:

- defining the flowering period;
- identifying the seed maturation period (including when seeds can be collected);
- determining if seeds are stored on the plant or released;
- quantifying seed survival rates in situ using seed viability testing; and
- identifying a list of pollinators.

Methods

1. Record the reproductive status/phenology (vegetative, buds, flowers, fruit) of all *Pityrodia* sp. Marble Bar plants within the monitoring plots.
2. Record the number of inflorescences on one plant per plot (nominally the plant closest to the centre of the monitoring plot) to assist with the determination of the potential quantity of seed produced per plant.
3. Under guidance (and with the relevant permit), collect plant branches with reproductive material to assess seed production per plant and per flower. Material should be collected from plants of varying ages (including from the first flowering of seedlings) to determine age when seed is first set (i.e. the first season of flowering may result in none or low seed set). This may require a collection at a different time to the collection of most data from the monitoring plots, and may require several trips to identify the ideal timing for collection of mature seed, although regular inspections by site personnel prior to commencing this activity (i.e. in the year before) would identify the timing more closely.
    (a) Where possible this material should be collected from populations that are within the proposed development footprint and are slated for clearing, however in order to collect material from a range of plant ages some material may have to be collected from elsewhere. Where required, this material should not be from within monitoring plots but should be collected from within a range of populations. The use of nets or similar may be required to collect seeds, depending on the reproductive biology findings including if seeds are dehisced from the plant or retained within the fruiting body and shed whole, and seed size.
    (b) When reproductive biology is better understood, the most efficient method of collecting seeds for other uses will be determined through discussions with relevant experts and reference to relevant publications such as Plant Germplasm Conservation in Australia (ANPC 2009).
4. Record any observations of pollinators or seed dispersal/predation. Notes will be made as to whether the pollinators target only *Pityrodia sp. Marble Bar* or if associations with other species are observed.
5. Investigate seed dispersal methodology, determining if mature seed is held on the plant (and potentially released as a result of fire or other disturbance) or shed when mature, and (if shed) by what method it is shed (e.g. passive seed drop or active dispersal like capsule explosion), and subsequent seed distribution (insect, wind, water).
6. Investigate the microhabitat for insect dispersal of seeds e.g. ant nests in the vicinity of recent germinants. Conduct research to determine soil seed bank storage.
7. Compare flower production and fruit/seed set (i.e. reproductive output) between natural and translocated populations as part of assessing the long-term success of any translocations

4.3 Environmental Associations

Objective

Describe the habitat of *Pityrodia* sp. Marble Bar in detail with the aim of identifying general physical habitat characteristics and specific characteristics that can be replicated in rehabilitated landscapes.

Actions

1. Describe in detail the characteristic physical habitat of *Pityrodia* sp. Marble Bar
2. Combine outcomes of the research with the habitat parameters previously modelled using MaxEnt (section 2.3) to prepare a complete listing of the habitat characteristics.

Timing

Refer to Section 6.

Responsibility

IB Operations Site Environment

Criteria for Success

At the end of the two year research period, FMG Iron Bridge has a thorough understanding of the physical habitat characteristics of *Pityrodia* sp. Marble Bar, particularly detailed soil physical (including slope, soil and rock types and sizes) and chemical characteristics.

Methods

1. Physical and biological habitat details will be recorded within the monitoring plots and provide details for at least 20 populations/sub-populations.
2. Record the soil physical structure at monitoring plots in more detail and describe the environment in geological terms. Soil samples will be collected for detailed chemical analysis. Additional accessible populations will be visited to garner additional information.
3. Plant root depth, architecture and fissure penetration will be assessed in the field using vertical profiles excavated through the soil and regolith. This investigation will be conducted on a small sample of plants within the development footprint that have approval to be cleared (subject to DPaW approval). Soil samples at varying depths where root growth is observed will be taken for detailed chemical analysis. Root diameters and anatomy will be examined, and evidence of fungal associations (i.e. mycorrhizal infections) will be observed, and samples collected for identification (if possible).
4. Investigate the hydrological characteristics of the soil including moisture retention within the soil, soil pockets and cracks in rocks.
5. Multivariate analysis will be conducted to find correlations between environmental factors and *Pityrodia* sp. Marble Bar occurrence. Physical characteristics that can be replicated in created landscapes will be described in detail.

4.4 Conservation Genetics

Objective

To understand the genetic variation and gene flow within the *Pityrodia* sp. Marble Bar population to identify protocols for seed collection for rehabilitation (and potential ex situ conservation) purposes (i.e. if seeds should be collected over a wide area or efforts can concentrate on accessible areas and within populations within the development area that will be destroyed).

Actions

1. Undertake genetic analysis of *Pityrodia* sp. Marble Bar, including variation and gene flow between all currently known populations at the time of publication of this plan (Figure 1).
2. Investigate inbreeding and outcrossing rates, including self-compatibility, among individuals and determine pollen dispersal distances.

Timing

Refer to Section 6.

Responsibility

IB Operations Site Environment

Criteria for Success

At the end of the research period there will be a clear understanding of genetic differences between the eastern and western populations, and if the genetic variation is significant. This knowledge will inform the development of a scientifically valid plan for collection of representative genetic material for rehabilitation and (if required) *ex situ* conservation.

Methods

1. Under the guidance of relevant experts and in accordance with conditions of relevant DPaW permit, collect suitable material from representative plants from all currently known populations (eastern and western populations) for genetic analysis. Material from both the eastern and western populations will be required to determine genetic variation. Material from population 50 that displayed greater colour variation than other populations should be gathered to determine genetic uniqueness.
2. The populations within the development footprint will also be included in the genetic analysis to identify the genetic diversity consequences of plant removal.
3. DNA sequencing will be conducted and analysed using standard population-genetic methods.

4. The results of genetic analysis will guide the number and location of genotypes to be incorporated in future *ex situ* conservation efforts.

4.5 Restoration

Objective

The objective is to develop suitable methods for re-establishing Pityrodia sp. Marble Bar on rehabilitated landscapes e.g. mine waste, tailings storage facility embankment walls.

Restoration conservation measures (i.e. translocating plants into a rehabilitated landscape) will be trialled using plants removed prior to clearing that would have otherwise resulted in their destruction. Monitoring will be required to determine persistence of translocated plants and determine if translocations results in a self-sustaining population.

Actions

1. Initially commence seed collection and collection of suitable material for propagation from a limited number of populations to develop suitable propagation methodologies. Suitable plants for initial investigation would likely include those proposed to be cleared. Seed dormancy investigations would be included, including determining if there is dormancy and the factors that can be used to break dormancy (e.g. smoke, heat, light).
2. When there is an adequate understanding of propagation methodology, commence in situ rehabilitation trials to garner a greater understanding of potential methods for long-term survival of the species. When population genetics are better understood, collection of material for restoration will focus on the outcomes suitable for restoring lost populations (i.e. those already included in the trial) and potentially (dependent on the outcomes of the population genetics research), other areas.
3. Conduct salvage trials (i.e. removal and transplantation into a rehabilitated landscape) of seedlings within the proposed mining area to determine if this is a valid restoration method.
4. Where possible, comparative trials in known suitable habitat (i.e. ‘control’ or ‘reference’ locations) will be included to provide additional information to assist with the identification of factors that are responsible for the success or failure of translocations

Timing

Refer to Section 6.

Responsibility

FMG Iron Bridge (nominated personnel)

Criteria for Success

1. Propagation methods are clearly understood at the conclusion of the research period (i.e. confirming if the species has potential to be successfully grown on rehabilitation sites, and the most likely successful method of restoration identified e.g. direct seeding, brushing, seedlings).
2. Sufficient propagation material has been collected from the population in the development footprint to ensure its genetic survival.

Methods

1. Under expert guidance, collect representative material to trial propagation techniques including seed collection and material for cuttings and other vegetative propagation methods (e.g. tissue culture). Initial material would be collected from plants within the development footprint and other accessible populations.
2. Commence investigations in relation to seed dormancy and methods of breaking dormancy (if dormancy has been identified as occurring), and germination rates of various treatment methods (including untreated seed).
3. Conduct salvage trials using seedlings within the proposed development footprint, transplanting them into a rehabilitation site.
4. Following research to identify suitable propagation methods, commence trials using various methods (e.g. direct seeding using treated seed if required, tubestock grown using methodology identified as most successful, plant debris mulching including untreated plant material and burning in situ if fire has been identified as breaking seed dormancy and on-plant seed storage has been identified) on rehabilitated landscapes.
5. Long-term monitoring, to be conducted annually during and for five years after the conclusion of the trial, will be undertaken. The timing for annual monitoring will be determined by relevant experts and may, at least initially, be conducted over two periods (post and pre-summer) for two years (commencing when on-ground trials commence) and thereafter annually, following the period of greatest seedling die-off. The monitoring will record the survival of the transplanted tubestock and germination and survival of seedlings for direct seeding and plant debris mulching trials if conducted. The resultant report will clearly outline the failure and successes of the various restoration methods.
6. Salvage trials will use whole of plants or cuttings, preferably on plants scheduled to be removed as part of the mining process.
7. Research regarding the environmental associations and modelling are anticipated to identify the important habitat factors associated with *Pityrodia* sp. Marble Bar, including substrate, slope/aspect, soil chemistry, hydrology, and (as far as possible). Any restoration sites will be created with these characteristics to maximise the opportunities for success.

5. *EX SITU* CONSERVATION

Ex situ conservation may be required if:

(a) genetic research undertaken determines the North Star sub-population to be genetically distinct and:

(b) trials of restoration methods are determined to be unsuccessful; and

(c) the disturbance associated with development of the Iron Bridge Project threatened either:

(i) the overall population of *Pityrodia* sp. Marble Bar; or

(ii) a distinct sub-population of *Pityrodia* sp. Marble Bar.

Contingency Objective

Where in situ conservation efforts to restore the genetically distinct sub-population of *Pityrodia* sp. Marble Bar that will be impacted by the Iron Bridge Project on a rehabilitation landscape are unsuccessful, to ensure the existence of genetic material that is representative of that genetically distinct sub-population in case there is a catastrophic event that destroys significant populations of that population.

Actions

1. If this contingency is enacted, long term storage of representatives of the sub-population of *Pityrodia* sp. Marble Bar that will be impacted by the Iron Bridge Project, in the form of:
   (a) seeds; and
   (b) cryogenic germplasm storage or other form of gene bank as appropriate at the time this contingency is enacted.
2. If the population genetics identify that the North Star sub-population is genetically distinct from others, ex situ measures to preserve its genetic material will be implemented prior to clearing of that population. If ex situ storage of genetic material is without ongoing cost to FMG Iron Bridge, wider ranging genetic material can be collected and stored as a resource for future translocations and research, to provide a contingency for the species as a whole;
3. Maintain suitable records of seeds and/or plant material collected for storage (location, date, description of donor plant etc.).

Timing

Refer to Section 6.

Responsibility

IB Operations Corporate Environment

Criteria for Success

Long-term storage of representative genetic material, if required.

Methods

1. Undertake research to determine the optimal seed storage conditions (research to identify seed maturation timing is listed above). When this is well understood, conduct seed collecting field trips at the most appropriate time, using the information gained from the conservation genetics study to ensure that adequate representatives of phenotypes or genotypes are collected for long-term storage.
2. FMG Iron Bridge (or its contractors) will be responsible for the collection of genetic material. Relevant experts and suitable reference materials (ie Plant Germplasm Conservation in Australia (ANPC 2009)) will be consulted to determine the most appropriate collection and storage methods, if ex situ conservation is required.

6. RESEARCH TIMETABLE

The following chart provides an indicative timeline for the Pityrodia sp. Marble Bar research and conservation plan outcomes. Any changes to the timeline will communicated in the Compliance Assessment Report.

Year	2017 - 2019[1]	Year 1[2]	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
4.1	Ongoing	X	X	X	X	X	X	X	X
4.2 (flowers)	Ongoing	X							
4.2 (seed)	Completed								
4.3	Completed								
4.4	Completed								
4.5 research	Ongoing	!	!	!					
4.5 trials	Ongoing			!	!	!			
4.5 monitor	Ongoing				!	!	!	!	!
5	N/A[3]								

[1] Research completed between 2017-2019.

[2] Research completed following triggering of Condition 7-10, i.e. disturbance to Pityrodia sp. Marble Bar.

[3] Conservation Genetics research (4.4) has demonstrated North Star sub-population is not genetically distinct (Ecoscape 2019), therefore Ex Situ Conservation (5) not required under the Plan.

! timing to be determined by availability of plants/seeds for salvage, and discussions with relevant experts.

7. REPORTING

IB Operations will provide an annual report to the CEO detailing progress against the activity milestones. The report will be submitted with the Compliance Assessment Report. The report will also be made available as per the conditions of MS 993.

REFERENCES

Astron 2018. Pityrodia sp. Marble Bar Research and Conservation Plan Studies Annual Report December 2017. Unpublished report for FMG Ironbridge.

Australian Government. *Environment Protection and Biodiversity Conservation Act 1999*.

Botanic Gardens and Parks Authority 2008, Conservation and Restoration Research Proposal *Darwinia masonii* and *Lepidosperma gibsonii*, Published in association with Mount Gibson Mining Limited and Extension Hill Pty Ltd.

Coffey Environments 2014, Significant Species Management Plan Abydos DSO Project, Unpublished report for Atlas Iron Limited.

Ecologia Environment 2012a, Canning Basin Borefield and Pipeline Single Phase Flora and Vegetation Assessment, Unpublished report for Fortescue Metals Group Ltd.

Ecologia Environment 2012b, North Star Access Corridor Flora, Vegetation, Vertebrate Fauna and Fauna Habitat Assessment, Unpublished report for Fortescue Metals Group Ltd.

Ecologia Environment 2012c, North Star Vegetation and Flora Assessment, Unpublished report for Fortescue Metals Group Ltd.

Ecologia Environment 2012d, Pityrodia sp. Marble Bar Targeted Flora Survey, Unpublished report for Fortescue Metals Group Ltd.

Ecologia Environment 2015a, North Star Slurry and Infrastructure Corridors Conservation Significant Flora and Vegetation Assessment, Unpublished report for Iron Bridge and Fortescue Metals Group.

Ecologia Environment 2015b, Re: Pityrodia sp. Marble Bar Revised Species Distribution Model, Unpublished letter to Fortescue Metals Group.

Ecologia Environment 2016, Iron Bridge North Star Stage 2 Pityrodia sp. Marble Bar Regional Survey 2015, Unpublished report for FMG Iron Bridge (Aust) Pty Ltd.

Ecoscape 2018, Glacier Valley Extension Flora and Vegetation Survey, North Star Project, Unpublished report for FMG Iron Bridge (Aust) Pty Ltd.

Ecoscape 2019. Pityrodia sp. Marble Bar Research and Conservation Plan Studies and Seed Germination Trials. Unpublished report for FMG Iron Bridge (Aust) Pty Ltd.

Ecoscape 2020. Pityrodia sp. Marble Bar Research and Conservation Plan Studies Unpublished report for FMG Iron Bridge (Aust) Pty Ltd.EPA 2014a, Report and recommendations of the Environmental Protection Authority. North Star Magnetite Project, Report 1514, June 2014.

EPA. 2014b. Report and recommendations of the Environmental Protection Authority: North Star Magnetite Project, Fortescue Metals Group Iron Bridge (Aus) Pty Ltd. Report 1514. Available from: http://edit.epa.wa.gov.au/EPADocLib/Rep%201514%20North%20Star%20Magnetite%20PER%20230614.pdf

Gallant, J. & Dowling, I. 2003. A multiresolution index of valley bottom flatness for mapping depostional areas. Water Resources Research, vol. 39, no. 12, pp. 1347-1359. Available from: http://onlinelibrary.wiley.com/doi/10.1029/2002WR001426/full

Government of Western Australia. 2015. Government Gazette No. 166, 3 November 2015. Available from: http://www.slp.wa.gov.au/Gazette/gazette.nsf/searchgazette/CAD6A4A88A0FA7AF48257EF00083C4C7/$file/gg166.pdf

Mattiske Consulting Pty Ltd 2007, A review of the flora and vegetation and an assessment of the groundwater dependent ecosystems in the Panorama Project Survey Area, Unpublished report for URS Australia Pty Ltd on behalf ofCBH Resources Ltd.

Phillips, S.J., Anderson, R.P., & Schapire, R.E. 2006. Maximum entropy of species geographic distributions. Ecological Modelling, vol. 190, pp. 231-259

Rio Tinto & DPAW. 2015. Rare and Priority Plants of the Pilbara mobile app edition. Available from: https://itunes.apple.com/au/app/rare-priority-plants-pilbara/id945178469?mt=8.

Trudgen, M. 2007, Supplementary Botanical Surveys, Rare Flora Searches, Assessment of Vegetation Condition and Identification of Groundwater Dependent Ecosystems for the Sulphur Springs Project, Unpublished report for CBH Resources, July 2007.

URS 2007, Panorama Copper-Zinc Project: Public Environmental Review (EPA Assessment No. 1664), Ecoscape comment: this EPA assessment number cannot be verified.

Van Vreeswyk, A.M.E., Payne, A.L., Leighton, K.A., & Hennig, P. 2004. Technical Bulletin 92 - An inventory and condition survey of the Pilbara region, Western Australia South Perth, Department of Agriculture.

Western Australian Herbarium. 2016. FloraBase Specimen Search: Pityrodia sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4). Available from: https://florabase.dpaw.wa.gov.au/browse/profile/37720.

Woodman Environmental Consulting 2009, Abydos Direct Shipping Ore Project Flora Assessment, Floristic Community Type Mapping and Impact Assessment, Unpublished report for Atlas Iron Pty Ltd.

Woodman Environmental Consulting 2011, Mount Dove Direct Shipping Ore Project Flora and Vegetation Studies, Unpublished report for Atlas Iron Limited.

Woodman Environmental Consulting 2012, Abydos Direct Shipping Ore Project Flora and Vegetation Studies, Unpublished report for Atlas Iron Limited.

Woodman Environmental Consulting 2013, Abydos Direct Shipping Ore Project Stage 2 Flora and Vegetation Impact Assessment, Unpublished report for Atlas Iron Limited.

Young, N., Carter, L., & Evangelista, P. 2011. A MaxEnt Model v3.3.3e Tutorial (ArcGIS v10). Available from: http://ibis.colostate.edu/WebContent/WS/ColoradoView/TutorialsDownloads/A_Maxent_Model_v7.pdf